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THE YOUNG

EXPERIMENTAL PHILOSOPHER;

OR, A SERIES OF

FAMILY DIALOGUES,

RATIONALLY AND FAMILIARLY EXPLAINING

THE VARIOUS

Phenomena of Nature.

RUDIMENTS OF REASON;

OR,

THE YOUNG

Experimental Philosopher:

BEING

A SERIES OF FAMILY DIALOGUES,

IN WHICH

THE CAUSES AND EFFECTS

OF THE VARIOUS

Phenomena of Nature

ARE

RATIONALLY AND FAMILIARLY EXPLAINED.

A New Edition,

CAREFULLY REVISED AND ENLARGED, BY THE

REV. THOMAS SMITH.

How charming is divine Philosophy!
Not harsh and crabbed, as dull fools suppose,
But musical as is Apollo's lute,
And a perpetual flow of nectar'd sweets. MILTON.

LONDON:

Printed for J. HARRIS, Successor to E. NEWBERY,
At the Juvenile Library,
CORNER OF ST. PAUL'S CHURCH-YARD.

1805.

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TO THE

YOUNG READER.

AS the following DIALOGUES may demand some small effort of imagination on your part, it seems necessary that you previously become somewhat acquainted with the scene where they were held.

Suppose yourself, therefore, the inmate or guest of a numerous, elegant, and happy family, in a romantic and remote spot in Devonshire. You will then have the satisfaction, not only of hearing, but of seeing, in idea, the various methods and curious contrivances of Sir Thomas Howard, the most vigilant of fathers, and of Lady Caroline Howard, the most accomplished and affectionate of mothers, to lead a beauteous and obedient offspring, through the mazes of nature, to that knowledge which can

alone satisfy the heart, and do justice to society.

Imagining yourself seated with this interesting party in the midst of a noble and spacious museum, you will perceive pleasure in every eye, and eager expectation on every young countenance, while the first dialogue is opened by Sir Thomas; who will, on every occasion, begin the conversation by laying down an explanation of the rules, and displaying the principles which his children must apply to, for the purpose of accounting for those *phenomena* which Lady Caroline will afterwards exhibit.

PREFACE.

THERE is, perhaps, no study more useful, nor more entertaining for young persons of both sexes, than that of NATURAL PHILOSOPHY; but to be truly serviceable, its principles must be simplified by explanations familiar to their immature understandings.

Many and great authors have devoted their labours to the illustration of this branch of science, and have done great credit to themselves, and promoted essentially the good of mankind, by their deep investigations on the subject. But to understand their writings, in which so many abstruse and technical expressions continually occur, implies, and actually requires, great previous knowledge, which cannot be expected from inexperienced youth.

The plan of the present work is calculated to facilitate the acquisition of useful knowledge, by inculcating the

rudiments of Natural Philosophy, and by a plain and easy method introducing the juvenile enquirer to an acquaintance with the secret springs and movements by which Nature operates, whose laws are unerring and invariable.

For the sake of perspicuity, and that the memory may not be overcharged by a retention not fairly to be expected from the tender faculties of youth, the form of dialogue has been adopted for the discussion; the various subjects are arranged under separate heads, and follow in that order which was judged most applicable to their connection with each other.

The observations of Sir Thomas Howard (the father of the family) which generally introduce each dialogue, explain general principles, and are such as will be found necessary to prepare the mind for more easily comprehending the various experiments by which the subject is afterwards elucidated.

These experiments too are so contrived as to be in general very readily put in prac-

tice by the young reader, as requiring only such apparatus as is either always at hand, or may be readily obtained for the purpose.

Throughout the work, as well in the prefatory observations, as in the practical or experimental parts of the dialogues, every possible attention has been paid to simplicity of style; the most familiar and easy terms have been always selected, and the whole subject is placed in that clear and perspicuous point of view so necessary in a work professing as this does, to reduce the principles of philosophy to the comprehension of children, or of persons of moderate capacities.

In some places, indeed, it has been found impossible to avoid the use of certain terms of science, or other words of some little difficulty, to which, however, no others could possibly be substituted with the effect of equivalent expression; but of all such words, clear definitions will be found alphabetically arranged at the end of the volume; so as to leave the reader without any diffi-

culty, and to supersede the necessity of frequently adverting to a dictionary for explanations.

Upon the first publication of this work, in three small volumes, the author expressed a hope, that it would be favoured with the particular patronage of those ladies and gentlemen who acted in the important capacities of conductors of schools, or as private tutors and governesses. This hope has been fully gratified, and the publisher, encouraged by the rapid sale of a very large edition, has now caused the work to be carefully revised and corrected; illustrated with copper-plate engravings; and, notwithstanding the introduction of much useful matter, he is enabled to present it to the public in *one handsome volume*, calculated to enlighten the expanding mind, and to assist the young student in his researches after useful and scientific knowledge.

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FIRST DIALOGUE.

ON PHYSICS.

Sir Thomas Howard.—THE knowledge of all those natural bodies which you see around you, my dear children, is what is generally meant by the word *Physics.*

The object of this science is, to teach us what those bodies are, by their properties, by the effects they have upon our senses, and by the laws according to which they mutually act on each other.

This constitutes the principal difference between *physics* and *natural history;* which last only tends to inform us, what the productions of nature are, and to point out the sensible dif-

ferences by which they are characterised, according to their kinds and their species.

One thing, my children, I must particularly observe: it is, that in the science of physics, you must never admit of any causes but those which are in themselves true and sufficient to explain the *phenomenon* in question: and, as this last term will frequently recur in the progress of our conversations, you should form an early and distinct idea of what is meant by it: it is used to signify the disposition and the motion of bodies, in respect of each other; provided this motion and that disposition do not immediately depend on the agency of some intelligent being.

One of the first questions usually proposed concerning bodies, is, whether or not, in so vast a variety, there be but one and the self-same matter?

Much time has been uselessly and unphilosophically lost on this subject. Those who pretend that all matter is homogeneous, or of one kind, say, that, in the beginning, the Author of Nature created only one universal matter, and that the different bodies were the result of the different combinations to which he afterwards subjected it.

Those on the other hand, who maintain that matter is heterogeneous, or of various kinds,

assert, that, in the creation of the universe, various principles were formed at one and the same time, and that, consequently, all the elements of bodies are so many distinct and particular works of the Supreme Being.

But, quitting so idle a dispute, it may suffice us to observe, that we commonly admit in mixed bodies, of five sorts of principles, viz.

Sulphur or *Oil*,
Water,
Spirit of *Mercury*,
Caput mortuum, or *dry-earth*, and
Salt.

By burning a splinter of wood, you may very easily distinguish all those elements.

In the *smoke* that arises from it, there is *water*; for, on holding your hand in it, you feel it moistened.

The *oil* it contained is known by the *soot* it leaves in the chimney.

You are convinced of the existence of its *spirit* by the *sharp* impression of the smoke on your eyes.

In its *ashes* you find both *salt* and *caput mortuum*.

These five elements abound more or less in all mixed bodies, and it is on their different mixtures that their variety depends: I scarcely

need add, that they are accompanied with a greater or less proportion of *air* and *fire*.

The next object you must attend to in *matter*, is its *divisibility*.

Matter is evidently divisible: but the question has always been, whether its divisibility is infinite?—For my part, I think the only rational answer that can be given on this head is, that, accurately speaking, division is not the destruction of matter, and that an infinite number of divisions can no more exhaust matter than one division can destroy it; consequently, if an ideal division be meant, matter is most undoubtedly infinitely divisible: but if we mean a real division, it is not; for this reason, that ingenuity has less power than fancy.

That matter is infinitely divisible in a mathematical sense may be easily demonstrated. For let the line A I (plate 1. fig. 1.) be drawn parallel to *a i* of any length, and at any certain distance, and divide it into as many equal parts AB, BC, CD, &c. as the small line given is to have divisions. Then draw through the extremities A *a*, and I *i* the straight lines A *a* O, I *i* O, till they meet in the point O; and from O draw toward the points of division B, C, D, &c. the straight lines OB, OC, OD, &c. which will likewise divide the small line *a i* into equal parts.

This operation may be performed, however small the given line, and however great the number of parts into which we may propose to divide it; for although the lines which we draw have always some breadth, whereby they may be at length confounded, yet in geometry lines have no breadth, and therefore are not liable to such confusion. However small, therefore, a line may be supposed, it is divisible into halves, and these may again be divided to infinity.

Art has gone a great way to excite admiration upon this subject of the divisibility of matter; and an exact scrutiny into the arcana of nature has brought us acquainted with parts of matter so astonishingly minute, that imagination is lost in pursuing them. I allude to the

Ductility of Metals,
Diffusion of Odours,
Existence of Animalculæ, and
Emanation of Light.

Gold-beaters have found the means of giving the matter upon which they are employed, an extent to which you will be hardly willing to give credit. Our great philosopher Boyle was, I believe, the first who observed that a quantity of gold weighing only one grain, that is, the four hundred and eightieth part of an ounce, acquires, under their instruments, an extent of fifty square inches. Now, there are mathe-

matical instruments on which an inch is divided into one hundred divisions, perceivable to an attentive eye. Multiplying then the length by the breadth, a gold leaf of one inch square will have ten thousand visible parts, and fifty square inches will consequently have five hundred thousand parts. And by the help of a microscope which magnifies the surface of a body one hundred times, the fifty millionth part of a grain of gold will be made visible.

To find the parts of a whole ounce visible to the naked eye you must multiply five hundred thousand by four hundred and eighty, and the product will be two hundred and forty millions, to which an ounce of gold is actually reduced by art.

This ounce of gold leaf, by being drawn on a silver cylinder, may likewise be run out into a length which, being properly divided, is equal to thirteen hundred and thirty-two miles, and by reducing the miles into furlongs, the furlongs into poles, the poles into yards, the yards into feet, the feet into inches, and the inches into hundred parts, which the eye may clearly distinguish, you will have an ounce of gold divided into ten thousand six hundred and fifty six furlongs ; into four hundred twenty-six thousand two hundred and forty poles: into two million three hundred forty-four thousand three hundred and twenty yards: into seven million thirty-two thousand

nine hundred and sixty feet: into eighty-four million three hundred ninety-five thousand five hundred and twenty inches: and lastly, into eight thousand four hundred and thirty-nine million five hundred and fifty two thousand visible parts!

In this process of wire-drawing, art is but the copyist of nature, for the silk-worm, by a wonderful instinct, spins the precious thread with which she forms her *coque* or shell.

This thread is of so amazing a tenuity, or thinness, that having measured three hundred yards of it, I found the whole weighed only two grains and a half; so that there must be sixty thousand yards to weigh one ounce.

The web of the spider, of which I have seen made, not only gloves, but beautiful stockings, much stronger than I could possibly have supposed, is incomparably finer than the production of the silk-worm.

To exemplify the divisibility of matter by

The Diffusion of Odours,

the most successful method is, to place a glass perfuming pan full, to a certain height, of orange-flower water, or spirits of wine charged with lavender, over the flame of a little lamp, or on a few red hot coals: the effect will be, that a copious vapour will be seen issuing from the pan.

On making this experiment in a *boudoir* fifteen feet every way, I found that in a few seconds the very smallest space of the room was charged with the perfume, without the least visible diminution of the liquid: now by calculating the air contained in this chamber, and paying proper attention to every other circumstance, we shall find that the quantity expirated does not really exceed the smallest grain of sand; but that by the action of the fire it is divided into five billion, eight hundred and four thousand seven hundred and fifty-two million, eight hundred and ninety-six thousand parts!

It is well known that a single grain of musk preserves its virtue twenty years without any perceptible diminution. If therefore we substitute this grain of musk in lieu of the orange-flower water, it will equally and as immediately fill the aforesaid apartment with its perfume. Now by renewing the air every day for twenty years, we daily repeat the above-mentioned prodigious number, which we found, by calculation, the room contained; that is, we must multiply 5,804,752,896,000 by twenty times three hundred and sixty-five days, which will give forty-two thousand three hundred and seventy-four billion, six hundred and ninety-six thousand, one hundred and forty million, eight hundred thousand particles, evaporated from

this single grain of musk, without any sensible decrement of its size.

In the extreme minuteness of the members of *Animalculæ* we find another proof of the divisibility of matter, by the help of microscopes, particularly the solar one.

They have a head which must be made up of skin, nerves, flesh, marrow, and membranes. They have a mouth to sieze, to savour, and even to chew their nurture. They have a stomach with coats adapted to expansion and contraction; of course it must contain the juices necessary for the fermentation and digestion of the substances with which they are nourished. They have entrails of different kinds and sizes, to faciliate nutrition and evacuation. They have eyes to guide and direct them, both in the pursuit of their prey, and how they may avoid becoming the prey of others; and, lastly, to effect motion and preserve life, they have veins, arteries, blood, or humours which supply its place. An eminent philosopher, Keil, by an ingenious supposition, that the particles of the blood of those animalculæ are to the particles of the blood of the human body, as the body of those animalculæ is to the human body, has found by calculation, that a volume of their blood, equal in size to a scarce visible grain of

sand, would contain more parts than ten thousand two hundred and fifty-six of the highest mountains of the globe would contain visible grains of sand.

I shall contract the proof of the divisibility of matter taken from

The Emanation of Light

to one single experiment and calculation.—If you place a wax taper, such as you may have six to a pound, in a calm night, and under a serene sky, on the top of a steeple or tower, you will be able to see it at the distance of six miles, that is, the particles it emits will fill the capacity of a sphere of twelve miles diameter. Now, I find by calculation, that during one second of time, there is consumed only one fourteenth part of a grain of wax; that is, the weight of one six thousand seven hundred and twentieth part of an ounce produces every second of time, luminous particles, surpassing in number the grains of sand contained in one hundred billion of globes, equal in volume to the ball of the earth.

On the subject of

The Void,

I can offer you nothing, my children, very satisfactory. Some philosophers contend that the universe is wholly full; others maintain that there are immense spaces absolutely empty.

Descartes supports the former opinion; Newton the latter. The great arguments of Descartes and his followers run thus:

Within the four walls of my study, besides myself, there are books, instruments, furniture, fire, and air: as long as the four walls contain these things, there is space betwixt them: but let the Deity, by his Almighty power, destroy these things, space disappears, and the walls become one body.

Newton's opinion is grounded on the following calculation:

He found that at the height of forty of our miles, the air must be a thousand times more rarefied, than on the surface of the earth: that at the height of eighty miles, the rarefaction must be a million times greater than on the earth; that at the height of one hundred and sixty miles, the air must be one billion of times more rarefied, or more approaching the void, than that which we here breathe. Hence he carries his calculation on to the moon, to the planets, and to the comets, where he asserts the void to be almost absolute.

For my part, looking on the question as it naturally strikes me, I admit of neither separately. That there is matter with bodies throughout the universe, is evident: it is also very clear that there is space or room for those

bodies to move in: the only vacuity therefore can be, the interstices or spaces betwixt these several bodies; and as the particles of which all bodies are formed, undergo various shapes according to their various destinations, so those vacuities will be sometimes greater, sometimes less, sometimes of one form, sometimes of another.

When these interstices are found in one and the same body, fluid or solid, they are called *pores*, of which you may form some idea, by observing the smaller vacuities that necessarily take place in a basket of apples or eggs.

All bodies upon which experiment can fasten are

Porous.

If upon a glass cylinder, open at both ends, you place a bason of any kind of wood, and fill it with water, by pumping the air from beneath it, the water will force its way through the pores of the wood, and fall drop by drop down the cylinder. It is likewise owing to this porosity of bodies, that aqua-fortis forces its way by dissolution through metals; and that air, water, crystal, and diamonds, give a free passage to light. Marble is so extremely porous, that it receives artificial colours so intimately as to be taken for the work of nature.

Throughout this and every future Dialogue,

my dear children, I would advise you to distinguish well, and never to forget, three things, with the nature of which I shall finish this first explication. These are,

Mass,

Volume,

Density.

The *mass* of a body is the quantity of gravi tating matter which it contains: it is entirely independent of the volume, and is determined by the quantity of the weight.

The *volume* of a body is the quantity of room or space that it occupies: it is independent of the mass, and is determined and known by multiplying the *length, breadth,* and *depth* into each other.

The *density* of a body is the relation of its *mass* to its *volume*; so that the greater the mass and the less the volume, the greater the density, which is determined and known by the quotient of the mass divided by the volume.

Specific weight is determined by the density; being the quotient of the absolute weight divided by the volume.

Dilatation

takes place, when the mass remaining the same the volume increases.

Condensation

or *compression,* takes place when the mass

remaining the same, the volume decreases; and

Elasticity

is the effort made by certain compressed bodies to resume their former situation.

As a consequence of this last, you may, for the present, suppose that gravitation, or the tendency of bodies toward the earth, is a species of elasticity endeavouring to regain its central situation.

Lady Caroline.—Sir Thomas has, with his usual kindness, communicated to you, my children, the principles of a very interesting subject. I understand from him, that it must be my business to put your attention to the test. It shall be in such a manner as to invite an answer, in spite of diffidence; and should that answer happen to be incorrect, it will be Sir Thomas's happiness to set you right.

[*Servants move the Experiment Table before Lady Caroline.*]

I take three short nails, and fixing them in these three respective holes, so that they form a triangle, about half an inch in height above the table, I place this half-guinea on the heads of the nails, and lay about half a thimble-full of the flour of brimstone immediately beneath, and as much upon the half-guinea as it can conveniently hold. I now set fire to the brimstone, and beg of you, my dear George, to tell

me, in a few minutes, what alteration you observe in the half-guinea?

George.—If I am not mistaken, Madam, I see two half-guineas instead of one; and I suspect your Ladyship did not observe *that* when you began the experiment. Will you permit me to take it off and examine it?

Lady Caroline.—Certainly, George.

George.—I protest the half-guinea is split into two half-guineas, and what is still more astonishing, one half is so thin, that it scarcely carries any impression; while the other looks as if nothing had happened!

Lady Caroline.—Well, George, can you recollect any reason that may account for this?

George.—I really cannot.

Lady Caroline.—I see Kitty smiling; she probably may help you.

Kitty.—I imagine that this disunion in the half-guinea is owing to the pores of the gold, and the different, or, as Sir Thomas called it, the *heterogeneous* matter that invaded them; much in the same manner, I should think, as a knife separates a deal board. The more subtile part of the sulphur exhales, and insinuates itself betwixt the pores of the gold, already dilated by the action of the fire, and forms in the bosom of the half-guinea an horizontal layer of matter foreign to the gold, and which

I think I can perceive on the two planes that were separated.

Sir Thomas.—Your answer, my dear girl, is very accurate. I shall only add a word or two by way of illustration.

The same cause which disunites surfaces, obstructs re-union; for this purpose oil and lard are generally used to hinder a connexion that might otherwise be too intimate. Things humid, or moist, are used to prevent the adherence of things adipous, or greasy; and we employ absorbent powders when there is upon any surface a fluidity that might occasion an attachment. Thus we employ butter in layers when we roll pastry. The moulds in which we cast wax are always smeared with something liquid; and in manufactories of earthen-ware and china, the new-formed vessels are always placed upon dry sand. For this reason likewise we take care in physical experiments to clean and repeatedly dry the surfaces we mean to unite.

The experiment her ladyship has shewn is entertaining to the natural philosopher; but in the hands of avarice it becomes dangerous; for the adulteration of coin is often owing to this expedient.

Lady Caroline.—While Sir Thomas has been speaking, I have used a few drops of warm isinglass to mend the corner of this Tunbridge-

ware box; and have besides melted a few more drops of a composition, by means of which I have re-fastened the spout which had been broken off this tea-pot. Tell me, William, how a fluid can impart such strength to a solid body?

William.—The isinglass and solder which your ladyship employed, by their fluidity insinuated themselves into the pores of the bodies to which you applied them, and became a link of union. The substance of the isinglass is conveyed by means of the water in which it swims, so as to remain when the water shall have evaporated; and when the action of fire shall have ceased in the solder, the surfaces are knit together, and by the means of that composition, now no more in motion, they are hooked as it were, by it in every pore, and become one continued body.

Lady Caroline.—Here are two cakes of wax, which when I place together adhere very sensibly, and that in proportion to the force with which I unite them, so as apparently to make one body. I now separate them, and pour a thin layer of water on the undermost. But you see the effect: they no more adhere, and even a considerable degree of force will not make them re-unite. What is the reason of this, Elizabeth?

Elizabeth.—It is not the property of water to penetrate unctuous, or greasy bodies; its very application to them is extremely imperfect, owing to the *heterogeneity*, or the different nature of its elementary parts: and therefore the link of union, mentioned by my brother William, cannot in this instance take place by the interposition of the water.

Lady Caroline.—I have dropped into this tumbler a few thin leaves of copper, on which I pour aqua-fortis. What effect do you observe, Henry?

Henry.—I perceive, Madam, a slight ebullition, or boiling. The metal seems agitated; its volume visibly diminishes; the liquor fumes; it puts on a greenish hue; the leaves now wholly disappear, and there is a vapour rises from, and spreads above the glass.

Lady Caroline.—You observe well, Henry: can you account as well for your observation?

Henry.—I fear I cannot: but I recollect Sir Thomas having once told us, that the constituent parts of aqua-fortis are sharp pointed, and something like daggers in miniature. The pores of the copper, like sheaths, are ready to receive these spikes, and by the internal heat of the aqua-fortis, a violent motion commences, and urges forward the spicula, or darts, with such rapidity, that pore bursting on pore, the

immediate destruction of the leaf ensues. The green hue is owing to the mixture of two such substances; and the heat, as well as the vapour that rises above the glass, are the effects of the great motion of the parts upon each other.

Lady Caroline.—In this other tumbler I deposit a portion of steel-dust. Tell me, Fanny, what you observe.

Fanny.—The effects seem much the same as in the last experiment, except that the movement is more rapid and violent, and the colour appears reddish instead of green.

Lady Caroline.—What is the reason of this difference?

Fanny.—I must beg leave to ask your ladyship one question first: Was the quantity of file-dust in the second tumbler equal to the quantity of copper-leaf in the first?

Lady Caroline.—I am obliged to you, my dear, for attending to the circumstance. It was.

Fanny.—Then I think that the aqua-fortis has a better opportunity of exercising its power on the steel-dust than on the leaves of copper: for when matter is equal on both sides, that which is most divided offers most surface to be acted upon: therefore the aqua-fortis being applied at one and the same time to a greater surface, must proportionably display its strength. Besides, copper being, as I have understood, hea-

vier than an equal volume of iron, there must be less density in this last, and of course more voids; so that one single pore may be stormed by a greater number of spicula, or darts: the red colour I attribute to the mixture of these two substances.

Sir Thomas.—It is yet too early to expect reasons for the production of colours. These will be given in a future dialogue on Light. But I have just now a question to put to little Mary, who has not yet had any part in the conference.

Tell me, my dear, why our brook, that winds through the paddock, was so uncommonly muddy while we were this morning taking our walk.

Mary.—It had rained you know, very heavy about an hour before we went out; and the brook running fast by the sand quarry, must have received into its little bed the particles of sand, mould, and clay, that the rain carried along with it.

Sir Thomas.—Your answer has been so good, that I must trouble you for another.

Can you account for the flowers in your garden yielding a more delicious perfume in the cool of the evening, than in the heat of noon?

Mary.—Probably because the chilness of the evening makes the air shrink into itself, and

gathers together, in any one plaee, a greater quantity of the sweet vapours, so that we can take in and smell a great many of them at onee: but in the heat of the day, the rays of the sun spread the air too much, and the perfume having got too much liberty to wander, it is only now and then that our nostrils are gratified with a stray particle.

Sir Thomas.—Upon my honour, Mary, you have given a very exeellent account of the compression of the air by cold, and of its dilatation or rarefaction by heat. I shall not add a word to it, lest I might destroy the clearness and simplicity of the answer.—Once more, Mary: have you not frequently observed, that during the fervid heat of noon, herbs, plants, and flowers, droop so much over their stems, that they seem quite dead; but that the next morning they re-appear erect in all their former vigour and beauty?

Mary.—This results from my last answer. During the day the bosom of the earth cannot so quickly supply them with spirits, as they lavish their sweets on the hot ray that exhausts their essence; but when the sun is down, the excitement ceases, and the earth has then time to recruit their pores with a fresh store of juices and repair the consumption of the day.

Lady Caroline.—In this finger-glass, which

is almost full of water, I mix a considerable quantity of loaf sugar, so that the water becomes thickened by it: I now pour some drops of spirits of wine into the glass, and it must be obvious to you all, that the sugar, which before swam with the water, is now suddenly precipitated to the bottom. What is the reason of this, Edward?

Edward.—There is a nearer alliance betwixt the pores of water, and the spirits of wine, than betwixt those of water and sugar. The union therefore, of the two former is more intimately and suddenly effected by a more congenial application of their parts. The sugar must of course be deserted, and by its own gravity sink to the bottom.

Lady Caroline.—I have in this cup some chips of Brasil wood steeping in water, and in these other cups several small parcels of plants: if you observe, the water in which the Brasil wood is lodged, is very highly coloured, and the small knots of fine thread which I have put in the other cups are distinctly tinged with many vivid colours. Tell me, Sophia, how this may happen?

Sophia.—When the wood is cut from the tree, there are certain juices which dry up betwixt its fibres, and are now dissolved by the penetration of the water, which, intermixing

with them, assumes their colour. It is much the same with regard to the plants. Their dried juices expanding on the approach of the water, and being carried off by it, are conveyed into whatever substances it visits, and when the water evaporates, they again become dry in those substances, and not only form a part of them, but communicate their colours to them.

Lady Caroline.—The water I here used was cold, and took some time before it drew out the tints: into this cup I pour boiling water, and you may observe that the infusion is quicker and more deep than in the others: account for this also, Sophia, if you please.

Sophia.—The action of fire is here added to that of water; of course the liquidity is increased, the penetration rendered more easy, and the dilatation of the solid allows more room for the exudation of the juices.

Sir Thomas.—I must beg leave to put one question, by the way, to George. How does it happen that a stag may be followed by the hounds upwards of six hours, and very often without having him in sight?

George.—I should imagine, that at the commencement of the chace, the hounds must trust more to sight than to scent; but that after a certain interval a transpiration begins on the part of the stag, by which the corpuscula emitted

from his pores are conveyed to the nostrils of the hounds. The longer the run is, the wider the pores are opened, so that a greater quantity of corpuscula are sent forth; and the longer the hounds pursue the more they are heated so that their nostrils, the finest part of which is generally exposed to the air, become more open through dilatation and receive a greater portion of the stag's effluvia.

Lady Caroline.—Frederic, you are very fond of salt meat. Salt generally is used for the purpose of preserving bodies from corruption. I think I have a right to ask you the reason of this?

Frederic.—Corruption is nothing else but a displacing of parts, which changes the state of the particles of mixed bodies: whatever can keep these particles in the order they received from nature will necessarily hinder them from undergoing any unnatural change; and on the contrary, whatever gives place to an unnatural movement will become the cause of corruption. Now, saline particles, like so many wedges, fill up the small vacuities, support and prop the solid particles, arrest the progress of evaporation, and preserve, at least for some time, the natural state of the body. It is thus that the flesh of animals, when salted, is so long fit for the

purposes of society, and that preserves of many kinds may be had on any exigency.

Lady Caroline.—I take this lavender bottle, and turning its orifice into this bason of rose-water, I find that it is with difficulty I can raise any part of the water into the bottle. I likewise take this small funnel, and fit it to the neck of this other lavender bottle, which it exactly suits: I find that in neither case the bottles can be filled at once, but that it must be very gradually and slowly effected. Give me the reason of this, William?

William.—In both instances, the air in one vessel contends against the water in the other. To introduce any liquid into a bottle, it is necessary that the air should find its way out as the liquor forces its way in. If, therefore, the funnel be so closely applied to the neck of the bottle that the air cannot get out from between them, either the bottle must burst, or for one drop of liquor that enters, a proportional quantity of air must go out; and I believe, that this is the reason why the bottle, which is in the hands of the butler who decants it, makes that cadenced noise, that the French have celebrated in an *ariette* of imitative harmony. In a word, the air contends with the liquid by its elasticity, and the liquid with the air by its gravity.

Sir Thomas.—You seem, William, so much an adept in this subject, that I must request a reason for a phenomenon that very often happens in my cellar. If by the means of a gimlet I make a hole in the lower part of a pipe of wine, not a drop will make its appearance, however the pipe may be urged by motion.

William.—As there is only that one small orifice, the elasticity of the air that fills it is much greater than the gravity of the liquor that resists it; therefore things will remain in their original state: but, if an opening be made in the superior part of the pipe, then the elasticity of the impending air will aid the gravity of the included liquor, and both together will overpower the elasticity of the inferior and horizontal column of air. This, Sir Thomas, I take to be the origin of vent-pegs.

Sir Thomas.—I have another question to propose on the same subject. After having given a pipe of wine as much air as is sufficient, and then stopping it, the wine flows only during a certain space of time, and dwindles away at last into an almost imperceptible streamlet, although the pipe be as yet at least half full of wine.

William.—In proportion as the wine flows out, the inclosed air must be rarefied and expanded; now, it cannot be rarefied without becoming

weaker, the quantity still remaining the same. The greater space therefore left by the extracted wine becomes full of a thinner air, which has not force enough to impel the liquor forwards, counteracted as it is by the external column of air which has not felt the dilatation, and, of course, is not weakened as the air is, which you stopped up in the pipe, by its being forced to fill a greater capacity than it otherwise naturally would.

Lady Caroline.—One of my closet windows, a day or two ago, could not by all the strength of the footman's arm be shut, or brought to its former situation: and I have frequently observed, Kitty, that the timber-work about the house starts, cracks, and loses its justness of proportion. Can you think of any reason to account for this?

Kitty.—I have heard Sir Thomas say, that it is the nature of all fluids to flow round on all sides equally, or to run to a level; and as the atmosphere is in a state of perpetual variation, wood, as well as every other spongious matter, undergoes continual alternatives of moisture and dryness, owing to the absence or presence of vapours, which must necessarily cause a great difference in their volumes. A porous substance at one time increases in extent, at another it decreases; so that every effect of this nature is

but the dimension of a body increased by humidity, or diminished through dryness.

Lady Caroline.—How has it happened, George, that the wainscotting of our covered walk down to the grotto has lately bulged so much?

George.—A surface of a spongious nature cannot touch a moist wall without acquiring an additional extent; and even that surface which is nearest the humidity will become considerably more expanded than that which is further from it. These bulgings and disproportions in joinery would not, I presume, be half so frequent as they are, if it could be contrived to render the increase and decrease of surfaces at all times equal. In works of one piece, or in those fixed together by means of glue, the change would be scarcely perceptible, were there heat contrived proportionable to the moisture; but as it is, one side of the wainscotting becomes humid and larger, while the other remains dry and undiminished; hence clefts, bends, and flaws without number.

Sir Thomas.—But there are many of the doors in my offices which have warped, without touching or communicating with any humid wall. How does this agree with the account you have given?

George.—Very well, Sir: for, though the

doors in your offices touch no humid walls, they have that to cope with which is much worse—the dishonesty of your carpenters.—They join pieces of wood together which are very different from each other in respect of their susceptibility of the impressions of the atmosphere; and while one of the parts of one door might resist moisture for a fortnight, the other instantaneously receives it; so that while one part remains in its prior state, the other has received a very considerable increase, and bursts from its original situation.

Lady Caroline.—What is the reason, Elizabeth, that paint is generally used on the above occasions? And how does it counteract the effects of the ever-changing atmosphere?

Elizabeth.—The pores being stopped with a substance impenetrable to water, they not only become impervious to any future moisture, but that which is already lodged in them cannot get out, or change the disposition of their parts: there seems to be no other way of hindering the bad effects of humidity, in bodies which can suffer no material or visible alteration, but that which proceeds from moisture or dryness.

Sir Thomas.—I have frequently been witness to a contrivance of a very ingenious nature, and I should be glad to hear Henry give his opinion of the matter. In the quarries whence mill-stones

are taken, they cut out a kind of circular ridge round the stone they wish to sever from the rest of the rock; they then fill that ridge with wedges of green-wood, which they have taken care to dry previous to their using them, and after driving them in as far as they can go, they pour water over them. The effect is, that in a very short space of time, the circular stone round which these wedges were driven separates itself from the mass to which it belonged, without any other effort on the part of the workmen.

Henry.—The drying of the wooden wedges previous to their being inserted in the clefts of the stone, renders the absorption of the water afterwards thrown on them so quick, that the wood, rapidly increasing in volume, becomes an active principle on the passive stone, the inactive weight of which must consequently yield to an effort which necessarily must take place.

Sir Thomas.—Tell me, Frederic, how is it that in summer we perspire more, eat less, and are considerably more feeble than in any other season of the year?

Frederic.—Our perspiring in summer is owing not only to a greater expansion of our pores through heat, but also to the extraordinary dilatation of the fluids of our body by the same cause.

As for our eating less than at any other time of the year, it naturally follows for the above reason, that the digestive powers must be, through the loss of juices, greatly relaxed, and rendered unfit for the exercise of their functions.

That we and all other animals are then less vigorous, is another effect of the abovementioned cause, heat; with this additional observation, that the consumption of animal spirits is at that time greater than the reparatives for appetite, and the need for eating is consequently not so great.

Lady Caroline.—Here is an egg, Edward, which five months ago I covered with a slight common varnish, and a thin layer of melted wax: I now break it into this cup, and ask your opinion of it.

Edward.—I perceive nothing different from a new laid egg; the white and the yolk seem to be in as fresh a state as ever; and, if I am not mistaken, the reason is, that the substances your Ladyship made use of were of a nature to enter the pores of the shell, so as to hinder the external air from penetrating into the egg, and altering the disposition of its contents, whence would have been produced corruption, and an offensive smell, which in this instance is not the case; besides, the evaporation of the interior substance was by the same means prevented.

Lady Caroline.—Here are two stopples, one of oak, and the other of common cork; with them I yesterday shut the orifices of these two bottles: the consequence is, that the liquid in that which was shut with the oak has entirely lost its spirit and perfume; but the liquid inclosed by the cork is as strong as ever. What can be the reason of this, George?

George.—The more I reflect, Madam, the more I am at a loss. I really must refer it to some of my brothers or sisters.

Lady Caroline.—As none seem willing to venture an answer, I must beg Sir Thomas would assist us.

Sir Thomas.—This is one instance to prove how a trifle may sometimes puzzle the wisest heads. I have seen the soundest philosopher put to a stand by the most obvious question proposed by a child. In the present case the fact is very obvious, but the reason depends on knowing that the pores of bodies are extremely different. The pores of the oak are large, but at a considerable distance from each other; to bring them, therefore, nearer together, requires great exertion. The pores of the cork are exceedingly small; but then their quantity makes up for their size, for they are innumerable; the distance therefore between them, being almost infinitely small, the exertion to

bring them nearer to each other is proportionably less. Now as the neck of a bottle cannot without destruction endeavour to bring the pores of the oak to a contiguity, so as to hinder the entrance of air, or the issuing of the inclosed liquor, the consequence is, that the spirits will necessarily evaporate: but, as the pores of the cork are much nearer each other, the neck of the bottle can without destruction to itself, suffer the condensation and compression of the pores of the cork into each other, so as to effectually hinder either the spirits from flying out, or the air from insinuating itself into the bottle.

Permit me now, Lady Caroline, to beg you would dissolve any small bit of gold you may have about you with a little *aqua-regalis*: and then, be so good as to try the same liquid on a piece of silver: and while her ladyship is making the experiment, do you, George, attend to, and account for it.

George.—I observe that the gold is dissolved; and I likewise see that the liquid has had no kind of power over the silver. It occurs to me, that the principle you have just been giving us, Sir, again takes place in this instance. The gold, probably, is something of the nature of the oak, and having large and wide pores, receives without much obstruction the particles of

the aqua-regalis, which, when entered, separate the parts from each other, and occasion dissolution. The silver, of course, is of the nature of the cork, and its pores being as small as they are numerous, they cannot admit the too large particles of the aqua-regalis; and therefore, as no penetration takes place, no dissolution ensues.

Lady Caroline.—I have in these two bottles two sorts of liquids, which I have myself prepared in the following manner. As the experiment I am about to make is extremely curious and amusing, I trust my children will give a more than common share of their attention to it.

A few days ago I mixed one half ounce of a substance called *litharge* with seven ounces of distilled vinegar, and after having boiled the mixture during half a quarter of an hour, I strained it off, and procured a very clear liquor.

I afterwards put into a long-necked bottle one ounce of quick lime, with half an ounce of yellow orpiment, on which I poured six ounces of water, and let it remain unmoved during twenty-four hours: it was then strained off, and I procured another extremely clear liquor.

Both of those liquids you now see in the bottles before you. I take this new-made pen, and dipping it in the first liquid I write a few lines on this scrap of paper, which you may all observe disappear the moment the liquid dries.

The paper, you see, I put between the first and second leaf of Keil's Astronomy; it might be placed at the beginning of any book of four or five hundred pages.

I then, as you perceive, dip a small bit of cotton in the second liquid, and turning to the end of the volume, I rub the last leaf with a little of what it contains. The book I now shut for four or five minutes, and desire that Kitty may then open it, take out the paper, tell us what she observes, and, if she can, account for the appearance.

Kitty.—The paper your Ladyship put into the beginning of the book had not one visible letter upon it; but here I find the first line of Satan's Address to the Sun, written in a black-brown colour; and I can perceive no tracks of communication betwixt it and the other liquor, as there is not a single mark or stain throughout all the rest of the book.

This is very curious and surprising; but I think I remember enough to afford some reason for it.

By smelling to the bottle which contains the last of these two liquids, I find that the vapour it exhales is exceedingly strong and penetrating, as it affects my nostrils, even without uncorking it. Now, the vapour of any liquid is only the liquor itself divided into very small parts; and if it can pierce through a corked bottle, it cer-

tainly can make its way as easily through the more porous and softer substance of the paper: but I have often observed, that particular colours are formed by the union of particular liquids; and therefore the vapour will make its way by the easiest passage, which is through the paper, and will only stop its progress when it comes to be united with the first liquor in the beginning of the book; and as the black-brown colour absolutely depends on the union of both the liquids, or their vapour, no stain can be left in any other part of the book, as not one of its leaves was supposed to be tinged with the first liquor.

Sir Thomas.—My dear Kitty, the accuracy of your reasons has given me much pleasure. I have only to observe that these liquids are generally called *sympathetic inks,* but have nothing to do with the reveries of the ancients concerning *sympathetic* and *antipathetic qualities.* The reasons of the effects produced by those liquids are, as given by Kitty, founded in nature; but the reveries above alluded to are the offspring of disordered imaginations.

As a proof of Kitty's judicious ideas of those inks, I must mention, that having sometimes left on a table in the room where I had prepared papers to use the next day some of the second liquor, I found two or three hours after-

wards the characters very legible and distinct, which undoubtedly was occasioned by the vapours flitting through the room, and lighting on the papers already written on with the first liquor.

Lady Caroline.—Were I to make this small bar of iron red hot, it would in cooling become proportionably less than it was, and harder. How does this happen, Mary?

Mary.—When the bar is red hot, it is greatly dilated, and the violent motion of the fire spreads out all its parts; but, as it cools, the pores crowd in upon one another, and as it cools much quicker than it was heated, the compression is greater than the dilatation, and the pores becoming less, render the bar at once less and harder.

Sir Thomas.—I have a few useful questions to ask you, Sophia, on the nature of some of the experiments alluded to. Can you inform me in what this porosity of bodies consists?

Sophia.—It depends upon the manner in which bodies acquire their form, and on the assemblage and union of the elements or solid particles of which they are made up.

Sir Thomas.—Some bodies are more porous than others. Why so?

Sophia.—The elements which enter their composition have been slower or quicker in

uniting together; have been impeded or hurried in the junction, and consequently are more or less intimately connected, which occasions greater or less interstices and vacuities.

Sir Thomas.—Has this porosity of bodies any influence on the different weights we perceive in different bodies?

Sophia.—The weight of bodies is wholly dependent on the number or size of the pores by which they are distinguished from each other.

Lady Caroline.—John has brought me from the cellar a piece of ice, which you see I can compress with perfect ease: but the instant this flake becomes water, it is then incompressible. On the other hand, these pieces of wax, of brimstone, of metal, &c. are all equally susceptible of impression, whether they are in a state of liquidity or not. How is it, Henry, that liquors have not the property of being compressible like solids in a state of fluidity?

Henry.—I imagine the natural state of almost all bodies is solid. They only become liquid by a foreign matter penetrating their pores, and communicating by its superior exertion an unnatural activity, which breaks the connection of their parts, and forbids almost any kind of adherence. Thus mould when incorporated with a sufficient quantity of water, becomes fluid dirt. Ice itself ceases to be such, the mo-

ment a more subtile fluid, known by the name of igneous matter, has penetrated its parts, and has carried motion enough among them to disjoin them from each other. When, therefore, the question is put, why solids may be compressed and liquors may not? the answer I should offer is, that the foreign matter which gives fluidity to solid bodies may be expelled, and by its dismission from a body to which it does not naturally belong, give room to compression: whereas the fluidity of liquors depending entirely on the conformation and elementary simplicity of a matter which is all its own, and without which it would cease to exist, its inflexibility becomes its nature; and as there is nothing to be dismissed from it, so there is no possibility of compression.

Sir Thomas.—I have tempered this piece of steel, William, that is, I have suddenly cooled it in water the moment I took it red hot from the fire; and now, upon breaking it, I find that its grain is considerably coarser than it was before; I wish you would endeavour to account for this: but before you do, I must inform you that steel is not a particular metal by itself; you must consider it as *prepared iron,* although there are mines in which it may be immediately found. The sort most used, and, indeed, the finest, is that which is made of iron, forged, so

as to introduce into its pores a certain quantity of saline and sulphureous parts, in order to increase its hardness, and render it fit for being tempered. By a degree of heat which is immediately given after the steel has been tempered, and is called *nealing*, the too great hardness acquired in tempering is reduced to a more moderate temperature.

William.—I should suppose that the action of the fire drives from the internal particles of the steel a great quantity of the salts and the sulphur contained in it, without forcing them wholly to quit the mass; for I have often observed, Sir, that while you amused yourself in the fusion of mixed and heterogeneous matters, the fire always procured an union of like parts, and therefore when its action increases to a certain pitch upon the steel, it deprives it of its salts and its sulphur, in such a manner that when the steel undergoes tempering, all its principles, though still the same, are variously mixed. Previous to its being heated, the saline, sulphureous, and metallic parts, extremely divided, and intimately mixed, make up one whole of a more uniform texture; yet more heterogeneous notwithstanding, since each particle partook of three or four several sorts of matters that enter into the composition of steel: but after a sufficient degree of fire, the salts and

the sulphur drawn forth, and mixed together separately from the metallic parts, make a more homogeneous whole, though more porous and less connected, in respect to the globules of salts and sulphur.

I therefore answer, that the reason why the broken steel you hold in your hand appears with a more coarse grain after being tempered, is, that the metallic particles, which by their colour are the most conspicuous, are gathered together into globules, separated from each other by the salts and the sulphur.

Lady Caroline.—Your answer, William, has been so satisfactory, that I must trouble you with a doubt of my own on the subject of tempered steel. I have always observed, that a piece of steel after having been tempered, is larger than it was before. What is the reason of that?

William.—I have already observed, Madam, that when it is red hot, the commotion within it is exceedingly great, and its constituent parts are violently torn from each other: the water seizing it in this situation, checks its returning to its former intimate, and more compact original union.

Lady Caroline.—But steel, by being tempered, becomes not only larger but harder. How does this happen, Frederic?

Frederic.—By what my brother William has already mentioned, I should imagine that since the water co-unites all the like particles together, their union must be much more perfect than when they were of a more mixed nature, previous to the tempering: now, hardness always depends on the degree of union of two constituent bodies, and therefore water cannot make that junction more close without making the steel harder.

Lady Caroline.—Tempered steel breaks much easier than that which is not tempered. Do you know the reason of this, Edward?

Edward.—I understand from what has been said, that after tempering, the salts and the sulphur are amassed together, and the metallic parts conglomerated into globules: now, as this is the case, their surfaces cannot touch each other in so many points as their particles had done before they had been tempered. A separation must of course take place more easily in one instance than in the other.

Lady Caroline.—Why, then, George, does *nealing* render the tempered steel less frangible and more flexible?

George.—A moderate degree of fire gives, in some measure, a new existence to the former intimacy of the dissimilar parts, and recovers what the excessive chill had overdone: it is

doing nothing else but creating, by a moderate fire, a mean state betwixt untempered steel and steel tempered too much.

Lady Caroline.—How is it, Elizabeth, that cold renders a body more elastic?

Elizabeth.—I think it owing to its condensing it; the parts are then more elastic, when they are more tightened, more compact, more solid, and more firm: now, nothing so much contracts, binds up, and tightens, as cold.

Lady Caroline.—And why are bodies much less elastic in summer than in winter?

Elizabeth.—By the rarefaction of heat, that contraction which occasions elasticity in winter, is in a great measure lost in summer.

Lady Caroline.—I have heard it averred, Fanny, that there is no such thing as perfect elasticity. Can you tell why this may be true?

Fanny.—When a body is in a state of unbending itself, it seems absolutely necessary that many of its solid parts which mutually touch, should repel and withdraw from each other; and that, by this means, they should suffer a considerable degree of friction: this produces a great obstacle to motion, and destroys a large portion of the strength of the spring.

The most solid and polished bodies, which are remarked to have the least pores, probably

have the greatest degree of elasticity, because they are less subject to the effects caused by friction. Now there is no mixed body without pores, and therefore the spring must necessarily be imperfect through the contiguity and rubbing together of those pores. The only method, therefore, of rendering bodies as elastic as their nature will permit, is to hammer them until they become as close, firm, and compact as possible. By this hammering the pores become less and fewer in number; the adherence of the constituent particles is rendered more intimate; and the friction of many ill-united surfaces is destroyed.

THE

SECOND DIALOGUE.

ON MOTION.

THE young family of Sir Thomas Howard had experienced so much satisfaction in the former Dialogue, on their entrance into the most pleasing of sciences, that with all the ardour of emulation they persisted in their importunities till they had obtained a renewal of the conversation.

Sir Thomas had left to Lady Caroline the choice of the subject for their second dialogue. She knew it to be his desire that they should regularly proceed in the study of nature; and as he had opened the first conference with an account of the subject of their future conversations, she conceived that the information her children had obtained of the *body* itself of nature, if I may be allowed the expression, should be followed by an insight into the laws of

Motion.

The party being met, and Sir Thomas informed of the subject proposed for elucidation, he thus addressed his family:

Lady Caroline's judicious choice, my dear children, has been such, that it claims the highest degree of attention. The laws of motion are the groundwork of all natural philosophy: without a perfect knowledge of them, we err at every step; by understanding them thoroughly, we shall be able to cope with every difficulty in our way to the sublimest of nature's efforts.

An account of these laws demands the utmost precision. You must therefore look forward to Lady Caroline's experiments on the subject for that pleasure which you will amply receive, provided you attend seriously to the short but comprehensive truths which I intend to lay before you.

Motion, generally called *local motion*, is the state of a body actually removed from one part of space into the part immediately succeeding it :—a body with a motion of rotation only has no local motion, because it does not change its place.

Natural philosophers have established three general laws of motion : the first of which is,

Every *body* which is not in motion, *remains* in a state of rest; and every body which is in motion, *continues* to move in an uniform direction, and with the same degree of velocity, till some *cause* forces it to change its state.

Suppose the ball A (plate i. fig. 2) to be in a state of rest ; it will remain in that state until some external cause give it motion. If it receive a single impulse from A toward B, it will go on in that direction, having no power of itself either to swerve from a right line, or to stop its course. If its progress be not impeded, its velocity will be the same at B as it was at A, and this velocity in an equal portion of time will carry it from B to C, and so on for ever, unless stopped* by some other body or cause.

The reason of this first law of motion is, That matter or body is, in itself, not only indifferent

* The force which compels a body in motion to stop is of three kinds, viz. the attraction of gravitation ; the resistance of the atmosphere ; and the resistance of friction.

to rest or to motion, but also to such and such a direction, to such and such a velocity.

The second law of motion is, That the change which happens in the motion of a body, is always in proportion to the cause which produces it, and continues along the line, in the direction of which that cause impelled it.

Suppose a ball in motion, and that a force, or cause, capable of giving it two new degrees of velocity, should effect a change in its motion, the consequence would be, that that motion would be doubled, or become doubly swift. This change would likewise be made along a straight line; for by the first rule, every body tends or endeavours to preserve the direction it received. The reason is simply this, that every effect is proportional to its cause.

The third law of motion is, That action and re-action are always equal and in contrary directions; that is, no action can take place on a body without experiencing a resistance equal to itself; and the actions of two bodies on each other are always equal and opposed in their direction.

This law is true, not only in the case of equilibrium, but also when an equilibrium does not take place.

Suppose two weights perfectly equal in the two scales of a balance; the first weight will

act as much upon the second weight, as the second weight will re-act upon the first weight.

Suppose again, that a horse possessed of one hundred degrees of strength, draws a stone with fifty degrees of resistance; the horse will not draw the stone with one hundred degrees of strength, but with fifty, the resistance of the stone destroying the other fifty.

The reason of this is, that when forces are at one and the same time equal and contrary, they must destroy each other.

A body is said to move by a simple motion in a straight line, when it is pushed onwards by one force only, or by many forces acting in the same direction.

If in equal times it runs through the same number of feet, one foot, for instance, every second of time, it is then said that it describes its line with a *constant and uniform motion.*

Should it run through one foot in the first instant, three feet in the second, five in the third instant, it is then said that it describes its line with *an accelerated motion.*

If, on the contrary, it runs through five feet in the first instant, three in the second instant, and only one in the third instant of time, it is then said that it describes its line with a *retarded motion.*

The force which produces an uniform motion, is called a *constant* and *uniform power:*

And that force which occasions an *accelerated* or *retarded* motion, is called a *variable* power or force.

The motion of bodies is called *power* or a *moving force*, when it is employed to communicate motion to other bodies, whether it endeavours only to move them, or actually does move them.

A *dead power* is that which is conquered by an *obstacle*; and a *living power* is that which overcomes a *resistance*.

Absolute rest is the situation of a body which remains in the same part of universal space, or which perseveres in the same relations of situation with all the objects which surround it:—and *respective rest* is the situation of a body which preserves and continues to keep one and the same situation in respect to those bodies which *immediately* environ it.

Compound motion is that by which a body is determined to move by the impulse of many powers, acting at once in different directions upon it.

When this takes place, either the body must remain *in equilibrio*, or it must move in the proportion of the velocities of the acting powers and receive a direction which proportionably partakes of all the directions of the powers which it obeys.

A body thus set in motion describes a *diagonal,* and a body describes a diagonal when it is impelled at one and the same time by two constant and uniform powers, the directions of which form an acute, obtuse, or right angle.

Suppose that on the ball A (plate i. fig. 4,) a force be impressed sufficient to carry it with a uniform velocity to B in a minute; and another force to be also impressed on the ball which alone would make it move to C in the same time; by the two forces acting together at right angles to each other, the ball will describe the diagonal line A D in a minute. Some of the heavenly bodies however, which are impelled by two forces, perform their motion in a circular curve, as A *a* D.

The *motion of refraction* is that taken by a body on its entrance into a new medium; it then changes its direction, and to this change the name of *refraction* is given, to shew that the direction of the body is, as it were, broken at that point where the two mediums meet and touch each other.

The *motion of reflection* is that by which a body springs back from another which it had met.

If an ivory ball be obliquely thrown on a plane surface, it rises, after striking the plane, and flies to the other side, by a motion which

natural philosophers call *reflected,* or by a motion of reflection.

Direct percussion is that of two bodies, whereof the *centers of gravity* are in the direction of their motions; in every other instance the *percussion* is called *oblique.*

I will now lay before you, as briefly as possible, the principal laws that nature follows in the shock of non-elastic bodies.

A moving body which strikes another body at rest, communicates to it its force in the proportion of the two masses. If the body which strikes has a mass equal to the mass of the other, it gives it one half of its force: if its mass is double the mass of the other, it imparts one third of its force; if its mass be only the half of the other, it communicates two thirds of its force.

A more swift body striking a more slow body that happens to precede it, divides the excess of swiftness in the proportion of their masses, in order to go on together after the shock with equal velocity. When the body more swift overtakes that which is less swift, the slowness of the one is an obstacle to the motion of the other: but this obstacle is moveable, and must partake of the excess of velocity of the striking body, in the proportion of its mass, according to the preceding law.

If two bodies shock each other with equal and

contrary forces, they spring back from each other with the same force; for since neither is victorious, they necessarily must recoil with equal powers. Of those powers or forces they lose nothing, since they in no manner communicate them; for it is obvious, that the body communicating force is the most powerful of the two.

If two bodies with contrary directions and unequal forces shock each other, they go on together, after the shock, towards the same place, in the direction of the strongest. In this case the strongest of the two must be victorious; for though it does not communicate a part of the excess of its force, it only divides it in the proportion of the two masses, in order to surmount every obstacle to its direction.

The only circumstance in which two bodies moving in contrary directions remain at rest, or become motionless, is, when, in consequence of the shock, the velocities are in an *inverse ratio* of the masses. On both sides the forces are kept *in equilibrio*, and this equilibrium produces rest in both.

Unequal bodies moved in opposite senses do not remain at rest after the shock, unless their forces be unequal.

A body in motion may, without any percussion, communicate a part of its motion to another body only by pressure.

The action of a body does not diminish its force, nor consequently its velocity, unless it forces the obstacle, or some part of the obstacle, to change its situation.

You see, my children, that it is my endeavour to shorten as much as possible these principles of motion, and convert them into brief maxims, that your memories may not have to encounter either confusion or difficulty.

To the above general laws, I shall now add those of elastic bodies.

You must in the first place carefully observe that there are in the shock of elastic bodies, two kinds of motions: a *direct motion,* by which the elastic bodies lose their former figure, and a *reflected motion,* by which the same bodies resume the figure, or form, they had lost.

The first law of those bodies is, that, in the shock, *direct motion* is communicated in the same manner as if the bodies were *hard:* the law of which I have already explained.

The second law is,

When, after the shock, two elastic bodies resume their former figure, the body that strikes acquires as much velocity to return back, as it had communicated to the body which it struck; and the body which was struck acquires as much velocity to go on, as it had at first received from the striking body.

To illustrate these laws, let us suppose two elastic balls *a* and *b* to be suspended by threads from adjoining centers. If *a* (plate i. fig. 3,) be drawn out of the perpendicular and directed towards *b* with six degrees of velocity, it will become motionless, while *b* will fly on in the direction of the former to *c*, with the whole six degrees of velocity.

If these balls had been simply hard, and not elastic bodies, they would have moved onwards after the shock with three degrees of velocity each; but on account of its elasticity, the striking ball *a* acquires three degrees of velocity to return back: it must therefore remain motionless, because it had preserved three degrees of velocity to go on. In the same manner the second ball, as elastic as the first, resumes after the shock its former figure, and, in the act of resuming it, acquires three degrees more velocity to go on; it must therefore proceed with six degrees of velocity.

This experiment may be made with two balls suspended in the air, as *a b*, fig. 5; but if it be attempted on a plane surface, the striking ball will continue to move after the shock; you must, however, take notice, that this motion is not the direct one the experiment alludes to, but a motion of rotation round its axis, which is totally distinct from the other.

If two bodies perfectly soft strike with equal forces, they will remain motionless after the shock: these bodies lose their force, as elastic bodies do, and nothing restores their forces, as they have no spring; they must therefore be motionless after the shock.

Gravity, or weight, is that force by which all bodies fall towards the center of the earth, when unrestrained by any obstacle.

Weight is the sum of the heavy parts contained under the same volume.

Central force is that which produces the motion of a body, perpetually endeavouring either to move from, or to approach its center of motion.

Centrifugal force is that by which a body endeavours to remove from the center.

Centripetal force is that by which a body is drawn or impelled towards the center.

The supporting point of a machine is that *center of motion* around which all the other parts move.

Resistance is the obstacle or weight which opposes the motion communicated by the acting power to the machine.

Power, or *moving force*, is one or many forces joined together to conquer an obstacle, or support its effort.

The *center of gravity*, in a body, is the point

around which all the parts of this body are in equilibrio, whatever be the situation they are placed in.

The center of a figure is the point which divides a body into two equal parts.

The center of heavy bodies is that center of the earth to which all sublunary bodies tend.

The *line of direction* of a weight, is a line drawn from its center of gravity to the center of the earth.

Friction is of two sorts. The *first* is that in which the same parts of a body are applied in succession to the different parts of another; and the *second* is, that in which the different parts of a surface touch in succession the different parts of another surface.

Friction of the first kind is exceedingly strong; and causes the breaking off of those small prominences which form the inequality of surfaces, as may be seen by the dust arising from rubbing two pieces of deal or marble against each other.—The second species of friction has considerably less efficacy than the other in abating motion. A billiard ball rolling along a table produces this last friction as well as the wheels of most carriages, unless they be trigged, in which case the friction is of the first pecies.

It is necessary to observe, that friction in-

creases by the increase of the surfaces and by pressure; but more by pressure than by the augmentation of the surfaces.

The consequences of friction are, that owing to it, clothes and moveables can last but a certain time; that knives, razors, hatchets, &c. soon lose their edges; that the hardest of bodies receive what form the workman chuses by the friction of the file; and that water-spouts never rise proportionably to the quantity of their motion.

With the foregoing principles, my dear children, you will, should your memory not fail in preserving them, be easily able to account for whatever question Lady Caroline may think proper to propose, or for whatever experiment she may be so good as to indulge us with.

Lady Caroline.—The word *question,* which Sir Thomas has just dropped, is a hint, my dears, which I will immediately make use of; as a few questions will not only exemplify the preceding truths, but throw light on many things that may follow.

When a stone is thrown against a middling-sized tree, a very visible emotion is perceived even in the branches most remote from the trunk; the stone then falls at the root of the tree, and remains motionless: but if you direct with ever so much strength the same stone against a rock, it falls at its root motionless as

before, without the least sensible sign of communicated motion. Tell me, Mary, what may be the cause of this difference?

Mary.—Every thing material opposes its inertness to the shock of other bodies, and the force with which it resists against motion is always proportional to its mass. Now supposing that the stone were sent with the same strength against the tree, and against the rock, the first, that is, the tree, containing much less matter in it than the rock, resisted too feebly entirely to consume the force which urged it to move, without being a little displaced; and this displacing became visible by the agitation of the branches. The rock, having a much larger mass, resisted completely; and the effort of the stone, distributed to a certain number of the parts of the rock, could not extend itself to all of them, so that the rock could not be displaced or agitated.

Lady Caroline.—How, Sophia, do swallows, and almost all birds which frequent the water, fly so long and so far?

Sophia.—As they have generally, small bodies, ample plumage, and very long wings, they have no need of repeating their vibrations, so often as other birds; and thus, as their fatigue is less, their flight may consequently be longer.

Lady Caroline.—On the other hand, Sophia, what is the reason that some birds fly so seldom and through so short a space; and why do sparrows, linnets, and all of the finch kind, fly, as it were, by leaps, never supporting themselves long in the same direction?

Sophia.—The shortness and unfrequency of the flight of some birds is owing to their being too fleshy, and consequently to the disproportion of their wings to the mass of their bodies; they are therefore obliged to repeat very often the strokes of their wings, which occasions frequent weariness. With regard to the sparrows, finch kind, &c. their wings are so short, that they can raise and support their bodies by a velocity, to which they can only give a few instants: while they rest a little in order to re-commence their flight, their own weight gains upon them, and makes them lose part of their already acquired elevation; their flight therefore can be nothing but a series of jerks and springs.

Lady Caroline.—How, Frederic, do certain birds support themselves during a very considerable time without any appearance of motion in their wings, at the same elevation?

Frederic.—This, Madam, I should suppose, is what is generally meant by *hovering*: their wings must undoubtedly move, but their vibra-

tions are so quick and so short, that the distance renders them undistinguishable. The great velocity of this motion may for some time make up for more extended strokes; but it is to be remarked, that hovering birds are forced, from time to time, to regain by a common flight the elevation they had imperceptibly lost, and to give relief, by a slower and more uniform motion, to the muscle of which the spring had been too much stretched by the rapidity of their former vibrations.

Lady Caroline.—And why, Frederic, do those domestic birds, which at certain seasons of the year become very fat, fly so little and so ill?

Frederic.—Because neither their wings, nor the strength to move these wings, increase in proportion to their bodies, in order to embrace, as they should do, a greater volume of air: for it is well known, that in every species, neither conformation nor strength follow the vicissitudes of plumpness.

Lady Caroline.—For what reason, Henry, is a ball always sent to a much greater distance, than an equal quantity of small shot, or leaden drops?

Henry.—This difference arises from the resistance of the air, which always acts in proportion to the surfaces offered to it; for each

small grain of lead does, as well as the ball, offer to the air which it divides, the half of its round surface; and when the weights are equal on both sides, the sum of the little hemispherical surfaces of the leaden drops greatly exceed that of one single ball.

Lady Caroline.—What is the reason, Elizabeth, of the difficulty which a fish experiences in making its way up against the current of a river?

Elizabeth.—I imagine the fish has a double resistance to encounter: one is the motion of the water, which is contrary to the direction of the fish; the other is the weight, or rather the inertness, of the volume of water to which its body corresponds, and which it must displace, as much as if the river were a stagnant pool. A man who walks against the wind, has just such another difficulty to surmount.

Lady Caroline.—In passing over a river with a contrary wind, the boatman generally furls his sail, and begs the passengers to be seated; for what reason, William, does he act so?

William.—Because by these means he at once diminishes the volume of the vessel, and gives less hold to the impetuosity of the wind.

Lady Caroline.—The wheels of carriages are always trigged in dangerous and rapid descents. Why so, William?

William.—One and the same point of the circumference of the wheel being, in this case, dragged over a succession of resistances on the ground, it becomes a friction of *the first sort*, and is a very considerable obstacle to the motion of the carriage. This will not happen when every wheel turns as usual on its axle-tree; their different points are then applied to the different parts of the plane over which they roll: this friction, in respect of the circumference of the wheel, is of *the second sort*, and its motion, being already very free, would become a great deal too much so, were it favoured by too great a descent.

Lady Caroline.—Why do clothes, furniture, trinkets, instruments, &c. last only during a certain space of time?

William.—The rubbing and friction to which they are perpetually exposed, gradually change their forms and their surfaces, and deprive them of those properties for which they were originally intended.

Lady Caroline.—Whence arises, George, the very black colour, so remarkable in the dirt of the streets of great cities?

George.—There is a continual and prodigious consumption in all populous towns of all kinds of iron implements and coals; the particles of iron, as well as of many other black substances,

are, through the friction of conveyance, incorporated with the dust, which rains have moistened, and feet and carriages have beat up into a kind of black mortar.

Lady Caroline.—Why do we, Kitty, rub with soap the rim of a box, of which the lid is too tight?

Kitty.—We thereby diminish the resistance of the friction, by filling up the pores of the surface with a fluid of fat substance, in order to give a more smooth plane, and consequently less hold to the other particles of the rough surface. Thus oil is used to facilitate the play of hinges; grease is used to rub the inside of the stocks of wheels, and by means of those interposed smooth bodies, the species of friction is changed. They are so many globules rolling betwixt the surfaces, and doing in miniature what we see done in a more obvious manner, by rollers placed beneath an immense stone or beam, for the purpose of making the conveyance more easy.

Lady Caroline.—Water-spouts, Kitty, never are seen to rise to that height to which they should ascend, considering the great quantity of their motion. What can be the reason of this?

Kitty.—The water is conveyed through a tube, and has afterwards to make its way through the air, in both which circumstances it expe-

riences great friction. The internal and immoveable surface of the tube delays it on one hand, and when it passes into the air, it must be regarded as making its way through another tube, the surface of which differs from it only by the thinness and mobility of its parts.

Lady Caroline.—How then do you account for the diminution of friction in the internal surfaces of large tubes, when their capacity has been augmented?

Kitty.—Although the surface of a large tube be greater than that of a more narrow one, it is less when compared to its capacity: for it is a well-known fact, that a round and cylindrical tube of two inches diameter contains four times more water than that of which the diameter is only one inch; and that the circumference of the first is notwithstanding only twice as large as that of the latter. Thus if the volume of water, which is four times as much in the greater tube, were contained in four tubes like the lesser tube, it would correspond to surfaces, of which the sum would be double the surface it already has: and, indeed, the more the capacity of the tubes is diminished in pumps, in aqueducts, and in fountains, the more the velocity of the water is impeded and delayed.

Lady Caroline.—Why, Fanny, do rivers flow more slowly when their waters are lower?

Fanny.—Because the whole friction of their beds is employed upon a very small portion of water, which thereby has scarcely any force to urge itself on.

Lady Caroline.—How is it that those rivers are most rapid when their waters are highest?

Fanny.—The friction they have to encounter from their beds and banks, is then divided to a more considerable mass of water, and can therefore offer less opposition to the motion of the fluid. It may be likewise said, that the brooks formed by the rain descending with rapidity from the sloping mountains, communicate their swiftness to the rivers which they enter.

Lady Caroline.—In great heats, all the movements of clock-work are greatly slackened. What is the reason of that, William?

William.—Many causes may possibly concur in this effect, but the principal cause that your Ladyship now alludes to, I take to be the increase of friction through the pressure of the pieces which heat has rarefied, and made too large for their situation.

Lady Caroline.—A piece of metal in the hands of a turner sometimes suddenly resists the motion of the bow, after having, during some time, turned with freedom and ease. How does this happen, William?

William.—This likewise results from the increase of friction through pressure: the metal, by being overheated, lengthens between the two fixed points that held it, and therefore must stop: to prove which, the readiest remedy is, to drop some water over it, by which, being cooled, it turns round with as much ease as before.

Lady Caroline.—Small pieces of mechanism, George, which perform their movements with ease and accuracy, are frequently found to be good for nothing when executed on a larger scale, although the very same proportions be rigidly observed. Explain this effect, if you please.

George.—Friction does not increase in the proportion of the surfaces only, but rather in that of the pressures, which frequently increase with the weight or solidity of the pieces. A surface of more weight or solidity presses more upon another surface; there must therefore be more friction, and consequently more force required to make those pieces act?

Lady Caroline.—Why, Mary, are drowned people never picked up at the place where they began to disappear?

Mary.—Because at the same time that the weight of their own bodies draws them down, they are forced onwards by the current of the water,

Lady Caroline.—All heavy birds, Edward, such as crows, pigeons, magpies, &c. when they wish to light on the earth, strive to give themselves a convex form, by curving their wings and their tail. Can you account for this instinct?

Edward.—When they bend their tails and their wings, their direction cannot be in a straight line; it must form a curve, which, on account of its greater length, must necessarily soften and break the rapidity of the descent: for the figure of any body, considered as actually being in a fluid, contributes very much to make that body lose or preserve its original direction. If, for instance, instead of plunging a globe into water, we should use half a globe or a hemisphere; and if this last be directed parallel to its flat bottom, as its figure stops it more on one side than on the other, it will not preserve its first direction, but will describe a curve line, although it moves in a very uniform medium. I have seen this often verified by an experiment as simple as it is common. Whenever any sharp-edged body, convex on one side, as an oyster shell, is thrown horizontally, it never follows the direction which was given it; and if you turn its convexity downwards, you will almost always observe it rise, in defiance of its own weight.

Lady Caroline.—The birds we have been speaking of, Sophia, when they are young, drop from the air in a very heavy manner, and frequently hurt themselves against the ground. Why so?

Sophia.—They descend to the earth by a line, or in a direction, that is not sloping enough, or enough inclined to the horizon, whether it be that they have not reached the maturity of instinct that would have taught them to assume that convexity of figure which would have saved them; or that the feebleness of their members, and the shortness of their feathers, do not allow them to make any effort against their fall.

Lady Caroline.—Why, Henry, do those who go to shoot fish in the water, direct the ball always lower than the object?

Henry.—I think, Madam, that it is because when one shoots obliquely or aslant in the water, the ball, instead of descending, rises. Besides, as we do not see the object we aim at, but by the rays of light which come obliquely to us from the water into the air, these rays suffer a refraction, and do not shew the object in its true place. Now as the refraction of light is contrary to the refraction of other bodies, the apparent place of the fish is more elevated than its real place.

Lady Caroline.—Why, Elizabeth, does a punch, or any flexible pieee of pointed iron, when driven into deal, frequently bend from the direction we endeavour to give it?

Elizabeth.—Its point obliquely meets with some parts harder than others, as it is very easy to observe in fir, in which those kinds of refractions often take plaee; for should the nail be long and slender, it is not an easy matter to drive it in a straight direction.

Lady Caroline.—Why, William, do those who shoot into the water always take care to be very near the plaee, or direct their shot from an elevated situation?

William.—Were they to act otherwise, the direction of the ball might become too oblique, and the lead might not even enter the water. A person on the opposite bank of the river would be in real danger of being wounded; and I have often heard it said, that in almost all sea fights, cannon balls are much more alarming in their exeeution, by their first touching the water, and then darting up by a motion of reflection, than by the original direetion that was given them.

Lady Caroline.—Can you account, Mary, for an amusement which you and I have often seen, and which the little boys told us was called *making ducks and drakes?*

Mary.—I remember you told me the reason of it at the time we saw them, and you said that any stone sharp round the edges, and thick in the middle, thrown as obliquely as possible on the surface of the water, rises at the very point where it touched it; because then, on account of the slantness of the jerk, the surface of the water does for the stone what a solid and impenetrable plane would do: and if the body has received a sufficient quantity of motion, when its own weight determines it again to another oblique fall, it causes another new reflection, which is often repeated five or six times following.

Lady Caroline.—Bodies without any spring, or of which the elasticity is very imperfect, are much better suited to break the effort of violence than any others. What is the cause of this, George?

George.—Because they gradually retard the velocity of the moving body, and render it motionless, by yielding considerably at first, but less and less by degrees. Besides, it is well known that there is no motion, how quick soever it may be, which is not effected in a finite interval of time: thus, when a ball drops to form a place for its hemisphere in soft clay, though our senses may induce us to think that the effect took place in an indivisible instant,

we must conceive the time of the sinking divided into many equal instants; during which, the sinking ball displays its force against the parts of the yielding clay. But this force diminishes every instant, by a proportion which increases much more than the time; for, in the second instant, the resistances are more numerous than in the first, since the ball, now more sunk, offers a greater surface to the soft clay that it must push back, but which opposes itself more forcibly to its being displaced, by the compression it has received.

Lady Caroline.—What is the reason, Frederic, that an oaken board stops the force of a ball at once, which a sack of wool deadens by degrees?

Frederic.—The wood resists at once, and receives in the first instant, all the force of the ball; whereas the sack yields little by little, and takes many instants of time to break the efforts of its violence.

Lady Caroline.—A hard body falling on one's hand occasions no hurt, provided the hand yields during the few first instants, instead of bearing up and stiffening itself against it. Give us the reason of this, Kitty?

Kitty.—The yielding hand deceives, as it were, the falling body, by allowing it more time. Thus a drum resists an infinite number of blows of the drum-stick, although it could

not by any means resist one blow alone, equal in force to all those it receives in an hour.

Lady Caroline.—What is the reason, Henry, that in order to stop a boat carried on by the current of water, you gradually slope, and gently wind against its strength?

Henry.—It is for the purpose of breaking by degrees the impetuosity. All obstacles which yield in this manner, divide the whole effort of the moving body, and arrest, by a repetition of short attempts, a power which would undoubtedly force them, if all its action were re-united against them in one single moment of time.

Sir Thomas.—On this black and highly-polished marble table I have spread an exceedingly slight layer of oil. I now perpendicularly drop this ivory ball upon it. After having struck the plane of the table, it re-ascends by the same line that it fell, but not quite so high; and I observe on the face of the table a small round spot, of the width of about one twelfth of an inch. Can you explain this phenomenon, Fanny?

Fanny.—The mark which you have observed upon the marble, arises from the shock and the compression of the parts of one of the two bodies, and probably of both: and as both the surfaces are now in the very same state they

were in before you tried the experiment, there is no doubt but that the parts re-established themselves: had this re-establishment been perfect, it would have sent back the ball with a motion equal to that which it had lost while it fell. This however, in the present instance, did not take place; as on one hand, the air resisted the ascent, and on the other, it is very likely, that ivory and marble do not re-establish themselves with the same velocity with which they may be compressed.

Lady Caroline.—I strike one of the strings of this guitar, Kitty, and it is not till after it has exhausted a great many balancings and vibrations, that it resumes its former state of rest. Tell me the reason of this.

Kitty.—The motion which sends the body off from its former situation, and continues from side to side during some time, is nothing but the re-establishment of the compressed parts, which will continue till the velocity of the first pressure be spent.

Sir Thomas.—I have seen, William, cannon-balls, shot horizontally, touch the earth, rebound many times, and leave on the ground tracts of their flight, much *more long than deep.* How does this happen?

William.—A bullet follows one curve line in sinking, and another in rising, and these two

lines meet at the point of ground where the *descent* ceases and the *reflection* begins. Now, as its velocity in falling is a great deal less than its horizontal motion, this last motion carries it a great way on, while it has very little time to descend to any considerable depth. Hence the great difference observed betwixt those two dimensions.

Sir Thomas.—A cannon-ball loses all its motion when shot against a strong tower, or a rampart. What is the reason of this, George?

George.—When one of two bodies is at rest, the velocity of the striking body diminishes in proportion to the mass of the body that is struck; motion must therefore become imperceptible after the shock, if that body which is at rest is infinitely larger than the body which struck it: for which reason the velocity that the ball retains after the blow, is to the velocity which it communicated, as its mass is to the mass of the obstacle which it struck; that is to say, as an infinitely little is to an infinitely large quantity.

Sir Thomas.—Vessels are almost always dashed in pieces when they strike against a rock; whereas, when the shock takes place against another vessel at rest, the damage is seldom considerable.

George.—As the rock yields not to the motion of the vessel, the parts of the vessel which

began the shock have already lost all their velocity, while the hinder parts of the vessel still retain their velocity; a change of figure must then necessarily take place; the timbers are driven upon one another, and, if the shock has been violent enough, break in pieces: whereas, if the vessel rides up against a floating body that receives and obeys its impulse, the fore parts that are exposed to the shock are not entirely stopped, and the hinder parts of the vessel only experience a gradual retardation of their velocity.

Sir Thomas.—A smith, Frederic, is always out of humour with too light an anvil, or with one that is placed upon an unstable flooring. Tell me the reason of this.

Frederic.—The iron upon which he is employed yielding along with its prop, his blows have not the effect they would have if the anvil were so immoveably placed as to hold in absolute rest the side of the iron which touches it, while the hammer strikes upon the other. Workmen, who are obliged to make use of the hammer, say that the blow was a *false one*, when the matter which they use shrinks from them, by its not being sufficiently supported.

Lady Caroline.—Tell me, Fanny, why a hare or a fawn is sooner stopped, and more desperately wounded, when it is shot in flank, than when it flies before the aim?

Fanny.—Because the respective velocity of the lead is then greater, and the animal runs in a direction, which does not much remove it from the sportsman, to whom it then becomes a kind of fixed mark, and must consequently receive the shot with all its violence.

Lady Caroline.—Why does it require, Edward, a greater effort to *return* a bowl upon a green, than to *stop* it by opposing one's foot to its passage?

Edward.—Because you must not only employ a force equal to its own to surmount its first motion, but you must likewise add all the force that is necessary to make it return back. The effort, however, of a moving body which strikes against another, may increase both by its velocity and by its mass. We must not therefore be surprised, that tennis players frequently experience their rackets to be too light, because, even in the supposition that the blow was given with the same velocity, its effect must be considerably less, if the mass with which it was given was too light.

Sir Thomas.—The artists who work in small rooms, as *planishers, goldsmiths, block-makers,* &c. place the block which carries the instrument upon a roll of mat, or something equivalent. What is the reason of this, William?

William.—It is to deaden the blows; for

without that precaution, a great part of the strength impressed by the hammer might be transmitted to the flooring, and thereby considerably endanger the timber works.

Sir Thomas.—Why, Frederic, are the ramparts for fortified places built with bricks?

Frederic.—If those ramparts were constructed with any kind of hard stone, the cannon balls striking those elastic bodies would communicate their motion to a greater depth, abstracting from the danger of the reflection of the splinters.

Sir Thomas.—Can you tell me why pistols do not carry so far as guns?

Frederic.—Pistols are too short for the purposes of guns: the lead is already gone forth, before the explosion of the powder is entirely accomplished. The fire, besides, has not time to pervade all the mass of the powder.

Lady Caroline.—Tell me, Elizabeth, why do not wind and water communicate their motion all at once to moving bodies, as solids do?

Elizabeth.—Solids, having their parts knit together, act with all the power of their masses; but the action of fluids is very different, on account of their parts being so very moveable; there is only that part of them which is immediately and directly exposed to the shock, that makes any kind of effort; the rest does not

lose its velocity, and therefore does not contribute to the general effort. It is only after a certain time that the moving body receives all the motion which may be transmitted to it, as one may easily perceive in the wings of windmills, and the wheels of water-mills, at the beginning of their motions.

Lady Caroline.—An arrow which offers its point to the resistance of the air which goes before it, flies a very considerable way, while another arrow, with the current of the air on its side, falls almost immediately. Explain this effect, Sophia.

Sophia.—The arrow which presents its point only to the air, meeting but little of that element, communicates and loses less motion of course: whereas the other arrow, having to encounter much more air, which it must divide, for the purpose of making itself a passage, communicates and loses a great deal more of its force: its motion, therefore, must soon cease, and its course terminate.

Lady Caroline.—When the extremity of a beam divides the air, why, Mary, may a man carry it with greater facility than in an another direction?

Mary.—Because it has a smaller body of air to resist when placed endways, than when it is carried sideways.

Lady Caroline.—Spherical bodies, William, turn round with great facility; what is the reason of that?

William.—A ball, or a sphere, touches a plane only in some points, and would but touch it in one point, were it perfectly round; these bodies, therefore, meeting with little or no obstacle to their circular motion, and having no hindrance on their own surface, it is very obvious that they will not easily stop, as they meet with scarcely any friction; and to the little they do meet, they offer just as little surface; they therefore must turn round with great ease. Hence the motion of a top must continue a very considerable time, as it can be said to move only on a point.

Lady Caroline.—Why, Mary, does the blow of one ball against another give motion to the second?

Mary.—The first ball communicates to the second the motion which it had itself received from the hand that sent it off.

Lady Caroline.—And why does a ball, when thrown up into the air, stop after a certain interval of time?

Mary.—It loses the force that the hand gave it, by communicating it to the air, which it is obliged to divide.

Lady Caroline.—Suppose, Fanny, that two

men with equal strength threw two bowls, the one upon a uniform pavement, the other on a bowling-green; which would go farthest? and for what reason would one go farther than the other?

Fanny.—The bowl on the pavement must certainly run farther; for the motion communicated to the stones, would be no sooner given than restored to the bowl: whereas the grass yielding to the other bowl, gradually receives its motion, but does not return it.

Lady Caroline.—Why, Mary, do you experience more satisfaction in a chariot than in a cart?

Mary.—Because the motion of the wheels and of the horses is communicated to the springs of the chariot, and to the leather thongs which support its body, by the slenderest connexions possible, whereas the motion of a cart is in no manner avoided, but fully communicated to the cart itself.

Sir Thomas.—I think, Lady Caroline, that it is now time to put a few questions to our little folks, relating to the more curious and interesting subject of *compound motion*; if your Ladyship will permit me, I will propose one to George.

Why, George, does a waterman, in order to get to the other side of a river, direct his

course to a point much higher than that where he wishes to land?

George.—The reason, Sir, seems very obvious, when we recollect that the boat forced onwards, in a direction which is not that of the current of the river, forms a motion of its own, out of the two forces of which it experiences the action: thus we always see, that when the current of a river increases, the waterman must proportionably exert his strength, if he means to arrive at the intended spot. If the increase of the waters shall have made the current much more rapid, the waterman must, if he does not exert an equal strength, direct his boat to a point much higher; and this is the general practice used by the watermen on the Thames; besides, it is very well known, that every moving body, such as a boat, must, when impelled by two equal forces at right angles, describe a diagonal.

Sir Thomas.—To your judicious reason, George, I shall add a remark or two.

Fish furnish us with very extraordinary instances of this compound motion. When they mean to go to one side, or to another, they give a smart blow to the water with their tails: as the fluid does not instantly yield when stricken, it serves as a prop to the body of the fish, for the purpose of turning to the right or to the left; but if the animal had been

at rest, and meant to pursue its way in a straight line forwards, its motion is then always preceded by two very quick blows of the tail, struck in opposite directions, the body at that moment receives a motion made up of those two impulses; it neither goes to the right nor to the left, but its direction is accurately between both.

This way of advancing onwards by oblique and opposite motions is likewise observed in almost every reptile, such as adders, vipers, and snakes. The adder and the viper have, in so very particular a manner, the habit of these compound motions, and combine them together with so wonderful an instinct, that they not only elude a very quick pursuit, but avoid by their sagacious windings the most diligent search.

Birds also, and almost all winged insects, have a compound motion, when they are in the act of turning. The method that instinct prompts them to is, to clap one wing, either with more strength, or with more frequency, as you may all observe in the flight of a butterfly. Through the variety of its compound motions it is perpetually rising, falling, winding, rushing, and fluttering, all which irregularities may be easily accounted for, by the unequal action of its little wings.

When a vessel, Henry, is in full sail, if a

person from the scuttle of the mast should drop an orange, the people on shore would perceive it making a very crooked line in the air, while those on board would aver, that it fell in a straight line, as they really saw it fall at the foot of the mast. Tell me the reason of this deception.

Henry.—The orange has two unequal directions, one of which is horizontal or level with the water, and is occasioned by the motion of the vessel: the other is a perpendicular direction, but a great deal stronger, and is occasioned by the weight of the orange. The orange, being given up to both those forces, obeys them in proportion to their respective powers; and as the horizontal motion of the ship is infinitely less than the perpendicular motion of the orange's weight, the straight line that it would fall through if the ship were at rest, will belly out, by the motion of the vessel, into a small curve, beginning at the scuttle, and ending at the root of the mast.

Lady Caroline.—I have seen a gentleman, Fanny, toss up an apple perpendicularly in the air, while he was in full gallop, and without stopping, catch it in his hand again. How can this be done?

Fanny.—For the very reason, Madam, given by my brother Henry: the apple, in this in-

stance, is endowed with two unequal impressions, and partakes of all the rapidity of the horse, by the horizontal motion it received from the horseman : it therefore gives to the forward motion, and to its own weight, as much space as suits the inequality of the impelling powers, and by a curve line must necessarily fall back into the hand that threw it, if the hand remain in the same attitude to receive it.

Lady Caroline.—My dear Mary, I have often thrown out from the window of my carriage, a piece of money, with a desire that it might fall into the lap of a poor person ; I have done the same thing when riding with your papa on horseback ; I have likewise endeavoured to throw a parcel to a person on shore, as I have been rapidly rowed down the Thames ; and on all these occasions, I could never direct the object to the place intended. What could be the reason of this ?

Mary.—In all those circumstances, the motion of the carriage, the horse, and the boat, must be as much attended to as the impulse of the hand ; for it is as natural and as common to the thing that is thrown, as to the hand that throws it ; and I believe that this may be the reason why little Rutland always falls when he leaps out of his carriage at our door, as his impatience will not allow him to wait the opening

of the door by his footman, or the stopping of the motion of the carriage by his coachman.

Sir Thomas.—That allusion, my dear Mary, is an excellent instance of the subject before us; but tell me, Edward, are there no means of avoiding hurt in accidents of this nature in case it were necessary to spring from the carriage?

Edward.—The danger does not arise from the too great obliquity of the compound motion, which people might think hinders the body from dropping soon enough to the earth, and thereby escaping the wheel; but the error lies in this, that when a person takes a leap from his carriage in motion, he springs from an unfixed ground; and falsely conceiving that the communicated motion of the carriage is a velocity of his own, he does not exert himself enough to avoid a very unexpected fall.

Lady Caroline.—Why does a nut, Sophia, when pressed obliquely, fly from one's fingers, and describe a diagonal?

Sophia.—As it is equally pressed by the two fingers, it can no more obey one than the other, it must therefore take a mean direction; thus, it is a small motion made up of two impulses, whereof the effects subsist, and preserve their relation to each other, although the causes may have ceased acting.

Sir Thomas.—If, Frederic, I should strike this

billiard ball with the edge of my hand not perpendicularly on its middle, but perpendicularly on its side, it flies forward at first as the nut did from the fingers; and after having advanced eight or ten inches, it returns back to a point about half way from that from which it had set off. What is the reason of this?

Frederic.—By striking the ball as you said, it acquires two sorts of motions, one in a straight line, which it first followed, and another of rotation round itself, in a contrary sense to its direct motion; as it happens to a suspended pulley, when its edge is obliquely struck. This last sort of motion is not perceived while the ball glides rapidly over the billiard table; but when the direct motion is sufficiently slackened by friction, the motion of rotation acting in a contrary sense brings it back towards the place whence it departed.

Lady Caroline.—Why, Mary, do the artificial suns in fireworks become larger and more beautiful, by their motion of rotation.

Mary.—The inflamed salt-petre throws out with great force, an infinite number of fiery tangents, and forms a plane much more expansive, than it could possibly be, did it burn without turning.

Lady Caroline.—Tell me, Kitty, what is the reason why all swift carriages throw the dirt far from their wheels during their motion?

Kitty.—All bodies, in whatever state they be, acquire, by turning round, a centrifugal force: thus the dirt of the roads scatters itself from the wheel, and the grindstone of the grinder would soon empty the little water-trough in which part of it is plunged, and would occasion a continual dispersion, if a bit of leather, or old hat, were not placed in such a manner as to drag along the surface of the water.

Sir Thomas.—While her Ladyship has been proposing her questions, I have ordered John to bring me this pullet: If you observe, Fanny, all I do is to place its head under its wing, and turn it swiftly round half a dozen times. You now perceive that it lies on the table, to all appearance dead, or dead asleep. What is the cause of this?

Fanny.—Although the pullet remains motionless, her stillness is less the effect of sleep, than that of being stunned by the confusion which you have thrown into her senses by the circular motion you have given them; and which, as long as it lasts, will hinder them from receiving their usual impression. It is the same with regard to children, who, after forming a ring, run round in pursuit of each other till giddiness makes them fall; for by this motion the fluids of the brain take a circular direction, and sometimes preserve it so long as to be very alarming.

Lady Caroline.—Having strewed a quantity of mixed spices upon this little salver, I give it a circular motion. Tell me, Elizabeth, what you observe.

Elizabeth.—I observe, Madam, that all the smaller spices fly to the centre of the salver, and that all the larger or heavier spices rush round the circumference. The reason of this I presume to be, what Sir Thomas has already told us,—that the force which divides a body from the centre increases in proportion to the mass of the body, when the velocities are on both sides equal: besides, the force that draws one body to the centre, may be the effect of the force that drives another body from it.

Sir Thomas.—For what reason, Henry, do sea-faring people so cautiously avoid all those places on the sea, and in great rivers, where they perceive the least sign of a vortex?

Henry.—Bodies floating on the surface of a circulating water, being lighter than the surrounding waves, must necessarily be driven to the centre of motion. Should a vessel, therefore, touch the edge of a whirlpool, it would irresistibly be drawn in, and would infallibly perish: but what is owing to an excess of mass, might in the same manner be effected by greater velocity. A body environed by any matter in circulation, though heavier than that matter, would, notwithstanding, yield to its centrifu-

gal force, if that matter turned round much quicker than it; in such a manner, for instance, that the degree of velocity in one surmounted the superiority of mass in the other. We have at once an example and proof of this fact, in those whirlwinds which raise from the earth straw, dust, sand, &c.; for it is always observed, that those bodies, though much heavier than the air in which they turn, are collected in much greater quantities in the centre of the whirlwind when it begins, and when they have not yet acquired all the velocity of the fluid.

Sir Thomas.—Here, George, is a tube of very strong glass, the diameter is eight-twelfths of an inch; I have poured some inches of water into it, and after having extracted the air from the remainder of its capacity, I have sealed it up over an enameller's lamp. You see me shake it up and down; the water, you may observe, rises all in a mass to a height of some inches; and when it falls again to the bottom, its noise and its effort are the same as those of a solid body. Explain this, if you can.

George.—Had there been air in the tube such as there is in the atmosphere, from the surface of the water to the top of the tube, on shaking the water a little, the impending column of air would take its place for a moment, but the water falling back would meet with the

air, which would retard its fall, and after a reciprocal division would sink down, while the air would rise to its own place; but when there is nothing but water in the tube, and there is no other matter to disunite it, it falls all together and at once; and the base of this liquid column strikes the bottom of the tube just as a solid cylinder of the same weight might do. Our barometer, being a well-made instrument, is in the same situation as the water in your tube. When I take it down, I am always afraid of the glass breaking, for the superior part of the tube being empty of air, the mercury acts like a solid body against the bottom.

Lady Caroline.—Why, Sophia, do bodies every day become more or less heavy than they were?

Sophia.—Because every day takes away or adds to the material particles of which their mass consists.

Lady Caroline.—I have hung up here, Sophia, a small morsel of fine sponge on one of the arms of this little balance; and I every day observe, that it is more or less light or heavy. Account for this if you can.

Sophia.—It is owing to its being exposed to the impressions of the air, the moisture of which frequently makes it heavier, as at other times it becomes lighter by the absence of that humidity.

Lady Caroline.—Why, Elizabeth, is float-wood lighter than green wood?

Elizabeth.—Float-wood has lost a great part of its substance, of its salts for instanee; and this is so true, that the *lyes* made of its ashes are seldom or never used in washing linen, on account of the small quantity of salt they contain.

Lady Caroline.—We never perceive, Edward, any accelerated motion in the fall of those heavy bodies, to which obstacles only impereeptibly yield; the weight of a clock, for instanee, or the weight that turns a spit. Can you explain this effect?

Edward.—In machines, such as your Ladyship mentions, the movement is moderated by means which every moment bring back the moving body to its original swiftness; that is to say, to that infinitely small degree of veloeity with which it would begin to fall, if it were free. To understand how a body may a long time continually fall without accelerating its motion, I picture to myself a bowl falling down a stair-case, the steps of which are rather large, in such a manner, that falling from the first upon the second step, it acquires only as much velocity as is necessary to arrive at the brink, by rolling, and then fall upon the third step, and so on; it is very evident, that at the

hundredth step, its fall will be exactly like that of its first step; because, I suppose, that every time it rolled on the surface of a step, it lost the velocity it had acquired by the preceding fall. Almost the same thing happens, though not so sensibly, in the weight of a clock; when one tooth of the balance escapes from the pallets, the fusee turns a little, the cord is let a little down, and the weight falls a little, but so imperceptibly, that the eye cannot discern it on account of the shortness of its duration; this fall, however, is quicker at its end than at its beginning. The resistance experienced by the next tooth, until it likewise escapes, soon destroys this small increase of velocity, and the second fall is effected like the first, that is, as if the moving body had just quitted rest, to begin motion.

Lady Caroline.—In a boat, Sophia, I have frequently been in danger of falling at full length, when it chanced to hit too suddenly against the shore. Can you account for this?

Sophia.—While the boat recoils, the fore part of your body still preserves its first direction towards the shore. Your feet, which belong in a manner to the boat, by your standing upon it, receive a contrary direction of going back. Your body obeys both the directions as well as it can; the feet go back, the head plunges for-

ward, and the middle of the body, having no support, falls.

Sir Thomas.—If a person be placed upon a cylinder and endeavours to leap forward, he falls. Why so, George?

George.—He gives his head a forward direction, while the round cylinder gives his feet a backward one; the head and feet follow of course their respective directions, and the body, by its fall, proves the experiment.

Lady Caroline.—I have stuck into the two ends of this dry stick, about three feet long, and as thick as my wrist, two pins; I now place two glasses, half full of water, on those two tables of equal height, distant about three feet from each other. I place the stick in a horizontal situation, so that the two pins bear upon the borders of the two glasses; I now beg of Sir Thomas to strike a violent and quick blow on the middle of the stick. You see that the stick is broken in two, how thick soever it was; and how fragile soever the glasses are, they are not only not broken, but not a drop of the water is spilt. Had I suspended the stick by two threads, the effect would have been the same. Account for this, William.

William.—The middle of the stick, I mean the point that was struck, compressed itself, and at once received the instantaneous impression of the blow: this impression by communication

passes on successively to the other parts of the stick, but too slowly to relieve the centre of the stick. It therefore breaks, but breaks in observing every law of motion that its situation demands. It cannot remove the mass of air beneath it; it cannot communicate its motion to any other yielding body contiguous to it, soon enough to avoid fracture; it therefore yields at once, before even the pins have been in the least affected by the stroke. We may look on the glasses as two props; the middle of the stick, as the extremities of two rays; and the blow, as the power applied to those extremities. The further they are distant from the glasses or props, the greater force they receive to descend beneath the blow: but the extremities near the glasses rise by the descent of the middle ones, in such a manner as not only to precipitate the fracture, but to save the props or glasses.

THE

THIRD DIALOGUE.

ON THE

MECHANICAL POWERS.

Sir Tho.—THE pleasure which you afforded me, my dear children, by your attention to our last philosophical dialogue, has been considerably in-

creased by hearing you express an unanimous wish for further instruction; and I have no doubt but Lady Caroline participates in my satisfaction.—I now request you to attend to a brief explanation of the *Mechanical Powers;* which may probably yield some amusement, at the same time that it will illustrate several parts of the preceding conversation.

In considering and comparing bodies in motion, we may do it either with regard to the quantity of matter they contain, or the degrees of velocity by which they are moved. The power required to move or to arrest the motion of any body is proportionate to its weight, and its force is increased in proportion to the swiftness of its motion. Hence the *momentum*, or the whole force of a moving body, is the result of its quantity of matter multiplied by the velocity with which it is moved: and when the products arising from the multiplication of the matter in any two bodies by their respective velocities are equal, the momenta or entire forces are so too.

To render this more plain, you may suppose a body weighing twenty pounds to move at the rate of two miles in a minute; and another body weighing only four pounds to move ten miles in a minute, the entire forces with which these bodies strike against any obstacle would be

exactly equal, and equal powers would be requisite to check their progress: for 20 multiplied by 2 gives 40, the force of the first body; and ten multiplied by 4 gives 40, the force of the second body.

Upon this simple principle, my children, depends the whole system of mechanics: and I wish you particularly to observe, that when two bodies are suspended on any machine so as to act contrary to each other, if the machine be put in motion, and the perpendicular *ascent* of one body, multiplied into its weight, be equal to the perpendicular *descent* of the other multiplied into its weight, these bodies (though perhaps very unequal in their weights) will balance each other in all situations; for as the *ascent* of one is performed in the *same time* with the *descent* of the other, their velocities must consequently be as the spaces they move through, and the excess of weight in one body is compensated by the excess of velocity in the other. Upon this principle, therefore, you may easily compute the power of any mechanical engine, for in proportion as the power moves more swiftly than the weight, so is the power augmented by the help of the engine.

The *mechanical powers* are six in number; the lever, the wheel, the axis, the pulley, the wedge, the screw, and the inclined plane. These are

called *mechanical* powers, because they enable us mechanically to raise weights, to move bodies, and to overcome resistances, which could not be effected without them*.

Of the Lever.

A *lever* is an inflexible bar of iron or wood, one part of it being supported by a prop or fulcrum, on which, as the centre of motion, all the other parts turn: and the velocity of every part is exactly proportionate to its distance from the prop. Therefore, when the weight to be raised at one end, is to the power applied to raise it at the other, as the distance of the power from the fulcrum is to the distance of the weight from the fulcrum, the power and weight will consequently balance each other: and as a common lever has very little friction on its prop, a trifling augmentation of power will be sufficient to raise the weight.

There are three kinds of levers, which I will endeavour to explain as briefly as possible.

A lever of the first kind has the fulcrum, or prop, between the weight and the power; but much nearer to the weight than to the power.

The second kind of lever has the fulcrum at

* It is a fundamental principle in mechanics, that whatever we gain in power we lose in time; and hence there is no actual increase of force acquired by the mechanical powers; yet the advantages we derive from them are inestimable.

one end, the power at the other, and the weight between them.

In a lever of the third kind the power is applied between the fulcrum and the weight.

A lever of the first kind is represented (plate i. fig. 6,) by a bar marked A B C, and supported by the fulcrum D. The parts A B and B C, on different sides of the fulcrum, are called the *arms* of the lever; the end A of the shorter arm A B being applied to the weight intended to be raised, and the power applied to the end C of the longer arm B C.

In making experiments with a machine of this description, the shorter arm A B must be as much thicker than the longer one, B C, as will be sufficient to balance it on the prop or fulcrum.

To illustrate its effects, let P represent a power equal in gravity to one pound, and W a weight whose gravity is equal to 12 pounds. Now if the power be twelve times as far from the fulcrum as the weight is, they will exactly balance each other, and a little addition to the power P will cause it to descend, and raise the weight W; and the velocity of the *descending power* will be to that of the *ascending weight* as 12 to 1, or exactly as their distances from the fulcrum, and consequently as the spaces through which they pass.

From an attentive observation of this figure, you may plainly perceive, that a man, who by his natural strength could raise only a hundred weight, will be enabled by this lever to support twelve hundred.—When the weight is less, or the power greater, the fulcrum must be placed so much farther from the weight, and thus it may be raised to a proportionably greater height: for it is an invariable rule, that if the intensity of the *weight* multiplied into its distance from the fulcrum, *be equal* to the intensity of the *power*, multiplied into its distance from the fulcrum, the power and weight will exactly counterpoise, and a small addition to the power will raise the weight.

To explain this more fully: In the figure now under consideration, the *weight* W is twelve pounds, and its distance from the fulcrum one inch, and 12 multiplied by 1 gives 12: the *power* P is equal to one pound, and its distance from the fulcrum is twelve inches, which multiplied by 1 gives 12 again; and hence it is obvious that there is an equilibrium between them.

The common steel-yard (plate i. fig. 7,) is a lever of the first description, and is used to ascertain the weights of different bodies by a single weight placed at different distances from the fulcrum or centre of motion. For if a scale be suspended from A, the extremity of the

shorter arm A C is of such a weight as will exactly balance the longer arm B C: if this arm be divided into as many parts as it will contain, each equal to A C, the pound weight P will serve for weighing any thing as heavy as itself, or as many times heavier as there are divisions in the longer arm. For example, if the weight P be placed at the first division in the arm B C, it will balance one pound in the scale at A: if it be removed to 2, 4, or 6, it will balance 2, 4, or 6 pounds in the scale. If the intervals between the divisions on the arm B C be subdivided into equal parts, any weight may be accurately ascertained to halves and quarters of pounds, or, if necessary, to odd ounces.

To levers of the first kind may be referred several instruments which are almost continually before your eyes, such as scissars, snuffers, pincers, &c. which are made of two levers acting contrary to each other: their prop or fulcrum is the rivet which keeps them together; the power used is the hand; and the resistance to be overcome is the piece of cloth, candle-snuff, or nail; which we cut off, or draw out, by their assistance.

A lever of the *second* kind has the fulcrum at one end, the power at the other, and the weight between them. And in this, as in the former, advantage is gained in proportion as the

distance of the power is greater than the distance of the weight from the prop or fulcrum. Thus if A B (plate i. fig. 8,) be a lever from which the weight W of six pounds depends at the distance of one inch from the fulcrum G, and a power P equal to the weight of one pound hangs at the end B, six inches from the fulcrum, by the cord C D passing over the pulley E, the power will balance the weight; and a little addition to the power will elevate the weight one inch for every six inches that the power descends

Under levers of the second kind may be classed doors, turning upon hinges, patten makers' knives, nut-crackers, oars, rudders of ships, &c.

In the third kind of lever, the prop or fulcrum is at one end, the weight at the other, and the power is applied somewhere between the prop and the weight. And here it is proper to remark, that in levers of this description, the intensity of the power must exceed that of the weight, in proportion as the distance of the weight from the fulcrum exceeds the distance of the power from it. Thus let E (plate i. fig. 9,) be the fulcrum of the lever A B; and W a weight of one pound, placed three times as far from the fulcrum as the power P acts at F, by the cord C going over the fixed pulley D: in

this case the power must be equal to three pounds, in order to support the weight.

To this kind of lever may be referred the bones of a man's arm; for when we raise a weight by the hand, it is effected by means of muscles, coming from the shoulder blade, and terminating about one tenth as far below the elbow as the hand is; and as the elbow is the center of motion round which the lower part of the arm turns, the muscles must consequently exert a force ten times as great as the weight that is raised.

You will easily perceive, my children, that this kind of lever is a disadvantage to the moving power; and therefore it is never used but in cases of necessity; such as in that of a ladder, which, being fixed at one end, is, by the strength of a man's arm, reared against a wall. In clock-work, also, the wheels may be considered as levers of this description; because the power that moves every wheel, except the first, acts upon it near the center of motion by means of a small pinion, and the resistance to be overcome, acts against the teeth round its circumference.

Of the Wheel and Axis.

The second mechanical power is the *wheel and axis,* in which the power is applied to the circumference of the wheel, and the weight is

raised by a rope, which coils about the axis as the wheel is turned round; and hence it is obvious, that power is gained in proportion as the circumference of the wheel is greater than that of the axis. To illustrate this, let A B (plate ii. fig. 1,) be the wheel, D its axis, and suppose the circumference of the wheel to be eight times as great as that of the axis; then a single pound P will balance a weight W of eight pounds. I also wish you to observe, that as the friction on the pivots of the axis is small, a trifling addition to the power will cause it to descend, and raise the weight; though the weight will rise with only an eighth part of the velocity of the descending power.

It is by instruments of this nature that water is drawn from wells in many parts of the country; but as they require little power to draw up a single bucket, the large wheel A B is dispensed with, and an iron handle is fixed on the point Q, which, by its circular motion, answers the purpose of a wheel. To the same principle may also be referred the capstan and windlass in ships; and the various kinds of cranes which may be seen at wharfs, warehouses, &c. In some of these, is a great wheel, where two or three men constitute the moving power; for as they step forward, the part they tread upon becomes the heaviest, and of course descends.

till it be the lowest. Sometimes, instead of men walking in the great wheel, cogs are set round it on the outside, and a small trundle wheel made to work in the cogs, and to be turned by a winch. But in both these machines it is necessary to have a little wheel G, called a ratchet wheel, with a catch H to fall into its teeth, which will support the weight, if the man walking in the wheel should unfortunately slip, or if the person turning the winch should accidentally quit his hold.

Of the Pulley.

The third mechanical power consists either of one moveable pulley, or a system of pulleys; some in a block which is fixed, and others in a block which is moveable, and ascends with the weight. A single fixed pulley, like the beam of a balance, whose arms are of equal length and weight, affords no mechanical advantage; for if two equal weights (plate i. fig. 2,) W and P hang by the cord B B upon the pulley A, whose frame *b* is fixed to the beam H I, they will counterbalance each other, exactly as if the cord were separated in the middle, and its two ends hung upon the hooks fixed in the pulley at A and A equidistant from its center.

But although no mechanical power is derived from the single fixed pulley, yet when two or more are combined into a system of pulleys, they will

be found to possess all the properties of the other mechanical powers. Thus if a weight W hangs at the lower end of the moveable block *p* of the pulley D, and the cord G F goes under that pulley, the half G of the cord must bear one half of the weight W, and the half F the other. Hence it is evident that whatever holds the upper end of either rope, must sustain one half of the weight; and if the cord at F be drawn up, so as to raise the pulley D to C, the cord will be extended to its whole length excepting that part which goes under the pulley; and of course the power that draws the cord must move twice as far as the pulley D with its weight W rises. It is therefore plain that a power whose intensity is equal to one half of the weight, will be sufficient to support it, because if the power moves, by the means of a small addition, its velocity will be double that of the weight; as will appear from putting the cord E over the fixed pulley C, and hanging on the weight P, which is only equal to half the weight W; in which case there will be an equilibrium, and a trifling addition to P will cause it to descend, and raise W through a space equal to one half of that through which P descends.

This example, my children, plainly shows, that the advantage gained is always equal to twice the number of pulleys in the undermost

block; so that when the upper block *u* contains two pulleys, which only turn on their axis, and the moveable block U contains two pulleys which rise with the block and weight, the advantage gained is as 4 to the working power. Hence if one end of the cord K M O Q S be fixed to a hook at I, and the cord passes over the two pulleys N, and under the pulleys L and P, and has a weight T of one pound hung to its other end at T, this weight will support a weight W of four pounds hanging by a hook at the moveable block U. And with an additional power sufficient to overcome the friction of the pulleys, the power will descend with four times as much velocity as the weight rises, and consequently through four times as much space.

A system of pulleys, having no great weight, and lying in a small compass, is easily carried about, and may be applied in many cases for raising weights, where other engines would be ineffectual. But there are three things which take much from the general advantage and convenience of pulleys as a mechanical power. The *first* is, that the diameters of their axes bear a considerable proportion to their own diameters: The *second* is, that in working they are apt to rub against each other, or against the side of the block; and the *third* disadvantage is, the

stiffness of the cord that goes over and under them.

Of the Wedge.

The fourth mechanical power is the wedge, which is made up of two equally inclined planes, D E F and C E F (plate ii. fig. 3,) joined together at their bases *e* E F O: D C is the whole thickness of the wedge at its back A B C D, where the power is applied: D F and C F are the length of its sides; and O F is its sharp edge, which is inserted into the substance intended to be split by the force of a hammer or mallet, striking perpendicularly on its back. Thus A *a* B (fig. 4,) is a wedge driven into the cleft C D E of the wood F G.

Now, my children, you must observe, there will be an equilibrium between the power impelling the wedge downward, and the resistance of the wood against the sides of the wedge, when the thickness of the wedge is to the length of the two sides, or when half the thickness of the wedge at its back is to the length of one side, as the power is to the resistance.

When the wood splits below the place to which the wedge reaches, the advantage gained by this mechanical power will be in proportion as the length of the back is to the length of the sides of the cleft; estimated from the top, or acting part of the wedge.

The wedge is of great importance in many

cases, where the other mechanical powers would be of little or no avail; in consequence of the momentum of the blow, which is considerably greater than the application of any dead weight or pressure, employed in the other powers. Hence not only wood but even rocks can be split by it, and in some parts of Derbyshire large mill-stones are easily separated from the silicious sand-rocks by the work-men boring horizontal holes under them in a circle, and filling them with wedges of dry wood, which gradually swell by the humidity of the earth, and in a few days lift up the mill stone without breaking it. I may also add, that wedges are used for raising the beams of a house when the flooring has given way from too great a burden being laid upon it; and even the largest ship may be raised several inches by driving a wedge below it.

Of the Screw.

The next mechanical power is the *screw*, but this cannot strictly be called a simple power, since it is never used without the assistance of a lever or winch; by which it becomes a compound machine, of very great force in pressing bodies together, or in raising great weights.

This mechanical power is composed of two parts, one of which A B, (plate ii. fig. 5,) consists of a spiral protuberance, called the *thread*, which you may imagine to be wrapt round a cylinder;

the other part C D, which is termed the *nut*, is perforated to the dimensions of the cylinder; and in the internal cavity there is also a spiral groove adapted for the reception of the thread. Now, my children, if you cut a slip of paper in the form of an inclined plane or half-wedge, and wrap it round a wooden cylinder, it will make a spiral answering to the thread of the screw; and if you attentively observe the ascent of the screw, it will appear to be precisely the same with that of an inclined plane.

With respect to the advantage gained by this power, there are two things to be considered, viz. the distance between the threads of the screw, and the length of the lever.

Supposing two screws placed before us, the circumferences of whose cylinders are equal to each other, but in one the distance between the threads is an inch, and in the other only one third of an inch, it is evident that the screw whose threads are three times nearer than the other must possess a threefold advantage. It is true, indeed, that the *height* gained in both screws is the same, one inch; but the *space* passed in that which has three threads in an inch must be thriee as great as the space passed in the other; and therefore, as space is passed in proportion to the advantage gained, it is sufficiently obvious that three times more advantage is

gained by that screw whose threads are one-third of an inch apart, than by that whose threads are placed an inch apart.

With regard to the lever F D, it is scarcely necessary to make any observations, as you must perceive that power is gained by it, as in levers of the first description, in proportion to its length from the nut.—It only remains, therefore, to remind you that there are two simple methods by which the mechanical advantage of the screw may be increased, viz. by using a longer lever, or by diminishing the distance of the threads of the screw.

Machines of this kind are used by book-binders, to press the leaves of the books together previously to their being stitched, and to reduce volumes to the smallest possible size for the pocket. They are also used for taking off copper-plate prints, for coining money, and in all cases where great pressure is required.

Of the Inclined Plane.

The sixth and last mechanical power is the *inclined plane*, and the advantage gained by it is just as much as the length of the plane exceeds its perpendicular height. To illustrate this, my children, let A B (plate ii, fig. 6,) be a plane parallel to the horizon, and C D another plane inclined to it; then supposing the length C D to be three times greater than the

perpendicular height G *f* F, the cylinder E will be supported upon the plane C D, and prevented from rolling down upon it, by a power equal to the third part of its own weight. You must therefore perceive that a weight may be rolled up this inclined plane with a third part of the strength required to lift or draw it up at the end; and hence you may clearly understand why two or three strong planks are frequently laid from ground-floor warehouses to the streets, on which heavy packages are raised or lowered with facility.

To the inclined plane may be referred all hatchets, chisels, and other sharp instruments which are sloped down to an edge only on one side.

Thus, my dear children, I have given you a brief account of the nature, properties, and advantages of the mechanical powers; which I hope will enable you to answer any questions Lady Caroline may think fit to propose.

Lady Caroline.—When I take hold of this billet of wood, by one of its ends, with a pair of tongs, why, Mary, does it rise up and obey my hand with much more difficulty than when I take it by the middle?

Mary.—When your Ladyship takes it by one end, the other has so much the more force to resist, as it is more distant from the tongs, and consequently from the *fulcrum*, or point of sup-

port; and I take this to be the reason why the longer the planks are on which we play at *see-saw,* so much the more easily do they bend.

Lady Caroline.—Why, Kitty, does a carpenter, who is about to carry a heavy joist, always place it on his shoulder as near the middle as he can?

Kitty.—By thus placing it, he has only the weight of the wood to carry, because the two ends balance each other; and the prop is only loaded with the sum of the two masses: but if he had placed it at the two-thirds, or at the three-fourths of its length, to keep it from falling he would be obliged to hold down with his arms the shortest end; and this effort would then balance the greater length of the joist on the opposite side; but it is very evident that he charges his shoulder with this additional weight only through ignorance.

Lady Caroline.—Why, Fanny, does that gardener I see from the window in the paddock, stoop so much forward, while he is pulling (by means of a rope) that tree to the hole he has prepared for it?

Fanny.—I imagine, that to the exertion of the muscles he adds a part of the weight of his body, to conquer the resistance against which he acts. But it seems that he has injudiciously chosen his ground; for I know the place

he stands upon is an ascent, and a slippery one too; and, as he has no better prop, I doubt it will be a considerable time before he will draw the tree to its destined place.

I suppose, it is to prevent inconveniencies of this nature, that ashes are generally thrown on frost-glazed places much frequented, and that strong points are affixed to horse-shoes during great frosts.

Lady Caroline.—The inhabitants of the more northerly regions, being almost always obliged to travel on snow, bind to their feet a kind of racket, a great deal longer and broader than any of our shoes. What is their intention in this, William?

William.—By this contrivance they take in a greater portion of the plane, or of the surface they walk on; the breadth of which supplies the want of solidity with a more extended prop.

Lady Caroline.—What is the reason, Kitty, that horses are so extremely fatigued with the labour of surmounting an ascent?

Kitty.—It is not only the burthen, which is then less supported by the ground, but it is, besides, the proclivity of this ground which offers them a prop, in a direction extremely oblique to their exertions; for their legs labouring against it, incline in the same sense as it does;

and the more parallel they become, the less are the feet supported. For which reason, in roads of this nature, winding inequalities are from time to time dug, for the purpose of facilitating the draught; imitating, in some sense, the steps of our stairs, which, presenting an horizontal plane to the vertical effort of the foot, are much better props, and surer points of support, than any portions of the inclined plane upon which they are built.

Lady Caroline.—Why, Frederic, are large wheels generally preferred to small ones?

Frederic.—The levers of the large wheels are longer, and every point of their stocks, which are incessantly pulled, lies in the direction of the traces, and at the height of the breast of the horses. Hence, as I have read, that the carriages of our ancestors had four large equal wheels, they were much more useful than ours, which have only two high, and two other low wheels. Four large equal wheels are four large levers, continually seized by their extremities, and urged on in a direction perpendicular to the traces.

Lady Caroline.—Then why, Sophia, do we put two small wheels to our carriages?

Sophia.—I should think, Madam, that it is to hold the fore part of the carriage in a kind of suspension, that the very first exertion of the

horses, in a difficult passage, may tend to raise up the front, in order to facilitate the disengaging of the back part of the vehicle.

Lady Caroline.—Since an inclined plane is always longer than a vertical one, both heights being supposed equal; and consequently, since a stair-case, a gentle slope, or a ladder obliquely raised, do not lead to any particular elevation by the shortest way; why, Henry, are those means every day fixed upon in preference to others, by which much time might be saved?

Henry.—When planes of this nature are chosen for the purpose of raising bodies (pipes of wine, for instance, from a cellar), the additional time employed is less a loss than a change of velocity into force; for, if the inclined plane delay the velocity of the descending bodies, there is required less effort to stop their fall; and when they are thus supported, their weight is always more easily surmounted, whether it be meant to leave them at rest, or to raise them up again. Besides, it is well known, that it is more easy to raise a body by a line parallel to a plane, than by any other direction.

Lady Caroline.—There are some edifices, Mary, which, though their perpendicularity be lost, still support themselves, and bid defiance to storms and time. How can this happen?

Mary.—I suppose, Madam, that their centre

of gravity is still in the right direction, and equally supported.

Lady Caroline.—Why, Fanny, do rope-dancers perpetually gesticulate with their hands and arms?

Fanny.—Because, the body they walk on being continually in motion, as well as inclined, whenever they perceive that the centre of their motion is not supported, they recover it into the line of its direction by extending an arm on the opposite side, using it as a lever, of which the weight is so much the more powerful, as its parts are more distant from the centre of their motion.

Lady Caroline.—Why, George, do corpulent people generally lean back?

George.—In any other attitude, their centre of gravity not being well enough supported, they would risk falling on their face. This inconveniency is particularly owing to the prominence of their anterior parts.

Lady Caroline.—Then why does a porter, with a load on his back, stoop forwards?

George.—He and his burthen have one common centre of gravity, which is seldom placed within the body of the porter, and which would be instantaneously lost, if he attempted to walk erect. He must therefore necessarily stoop forward, until this centre of gravity is situate in a line directly betwixt both his feet.

Lady Caroline.—And why, George, is a weight moved to and fro with so very little difficulty, when its centre of gravity is suspended in the air?

George.—There are then neither the frictions of a rough surface to get the better of, nor the force of weight to surmount.

Lady Caroline.—All two footed animals have their bodies inclined forwards when they walk, and turn them alternately to the right and to the left. Why does nature prompt this motion, Kitty?

Kitty.—As the line of direction always passes through one foot, while the other is in the air, the centre of gravity where the line of direction originates is supported by that foot. If this centre were not supported, both by stooping forwards, and by collateral endeavours, it would unavoidably tumble, and, reasonable or not reasonable, would bring down the biped in its fall.

Lady Caroline.—Small birds, Mary, perched on a tree at night, cling to a branch with only one foot, contract the other up under their plumes, and then turn their head to the opposite side, to nestle it under the wing, and sleep with tranquillity. How is this managed?

Mary.—They act so, that the line of direction may pass through the foot that clings to the branch, and that the centre, being supported on

one foot, may no more incommode them. This they effectually do by the contracted foot keeping a perfect balance or equilibrium with the inverted head.

Lady Caroline.—How is it, Edward, that where politeness induces us to incline the superior part of the body and bend the head forwards, natural mechanism, as well as politeness, makes us advance one foot before us?

Edward.—That the line of direction may pass through that foot, for the purpose of supporting the centre of gravity, lest an excess of civility might send us a little lower than we intended; as it would most unavoidably happen to whoever should attempt to pick up a pin from the ground with his heels close to the wall.

Lady Caroline.—The centre of gravity in a four-footed animal, for instance the horse, is somewhere about the middle of his belly, and seems to be supported by nothing. How comes it, Henry, that, even in full gallop, he does not fall?

Henry.—In the horse, the centre of gravity is supported in the same manner that the solid diagonal is, which is the prop of the whole mass; I allude to two legs, the fore right leg, and the hind left leg; since both of these, going always alternately to the ground, support the solid diagonal that tends from one right leg to

another left leg, and to which the centre of gravity corresponds.

Lady Caroline.—Why, Frederic, may those bodies, whereof the bases are more expanded, remain for many years hanging over them without danger?

Frederic.—While the line of direction passes through the base, the centre of gravity supported by it cannot fall: and while it cannot fall, the parts around it, being well cemented to it, and to one another, remain eternally attached to it, if I may use the expression.

Hence the famous towers of Bologna and Pisa, the hanging summits of which seem every moment threatening ruin, subsist still, and bid defiance to the united efforts of weight and wind.

Lady Caroline.—I have seen a cat thrown down from a three-pair-of-stairs window into the street; and though, in the first instants of its fall, its legs were turned upwards, yet it fell upon its four feet without receiving the least injury. How did this happen, William?

William.—The cat, suddenly seized with a natural fear, bent the bone of its back, stretched its belly, lengthened out its feet and its head, as in the effort and attitude of regaining the situation it came from. In this extraordinary motion, the centre of gravity mounts above the

centre of the figure, but not being supported, soon descends. While it descends to place itself beneath the centre of the figure, it turns towards the earth the belly, the head, and the legs of the cat; the fall of which is then so near the ground, that, instead of being even stunned, it flies off with all the rapidity that fear can prompt.

Lady Caroline.—Tell me, Edward, how boats are made to advance by the efforts of oars, and why they advance with greater rapidity as the strokes are quicker and more frequent?

Edward.—I imagine, Madam, when the water is struck with such rapidity, it has not time to yield, but becomes a kind of fulcrum, or support, for the lever, which the boatman employs. And, if I am not mistaken, the same thing which the waterman does with his oar, is performed by a swimmer, with his arms and legs; by fishes with their tails; and by aquatic birds with their feet, which are webbed in such a manner as to throw back a large volume of water.

Lady Caroline.—One day last summer, Kitty bought, as she supposed, a pound of filberts; but on trying them in my scales I found but twelve ounces instead of a pound, and yet she assured me the scale went down when the barrow-woman weighed them, as if there had been

full weight. Tell me, Sophia, how this could have been managed?

Sophia.—I presume, Madam, it might have been done, either by short weight, or by the scale in which the filberts were put being heavier than the other. I am also of opinion, that the same fraud might have been practised with just weights and scales, by making one arm of the balance on which the weights hung shorter than the other: for in that case, a pound weight would consequently be balanced by as much less fruit than a pound, as that arm was shorter than the other. In either of the two last cases, however, the deception might have been easily discovered, by changing the weights to the contrary scales.

Sir Thomas.—I once raised some water by our draw-well, and I found the difficulty increase in proportion as the bucket ascended nearer the top. What reason can you assign for this, Frederic?

Frederic.—Your question, Sir, alludes to the principle of the wheel and axis, which you have kindly explained; and I am inclined to think that the difficulty you speak of, must always occur where the wells are so deep as to cause the rope to coil more than once round the length of the axis; for by such coiling of

the rope, the difference between the circumference of the wheel and that of the axis is gradually diminished, and consequently a smaller advantage is gained and greater force required every time a new coil of rope is wound on the whole length of the axis, and the bucket ascends towards the top.

Lady Caroline.—I once saw, at some paper-mills, six or eight men apparently exerting all their strength in turning a screw, to press out the water from some newly-made paper. Tell me, George, how the power applied in that case ought to be estimated?

George.—Not by multiplying the power of one man by the number of hands employed, because as those men stood by the side of each other, the lever must have been shorter to every man in proportion as he stood nearer to the screw, and his exertions must have been less effectual than those of the man who stood at a greater distance. But the proper method is by an accurate estimation of each man's power according to his position, added to the power of the machine.

THE

FOURTH DIALOGUE.

ON HYDROSTATICS.

Sir Thomas.—AS the subject we are about to enter upon, my children, is as easy in itself as it will prove interesting to you, it requires but little previous knowledge. What I have to say, therefore, shall be eomprised in a few short principles, that I may not long detain you from Lady Caroline's more pleasant part of the business.

Hydrostatics is that scienee which treats of the nature, gravity, pressure, and motion of fluids in general; and of weighing solids in them.

A fluid is a body that yields to the most trifling pressure: Its particles are so minute that they cannot be perceived, even with the assistance of a mieroseope; yet they are evidently hard, sinee no fluid, except steam or air, can be eompressed into a smaller spaee than it naturally possesses; and they must be round and smooth, from the circumstance of their moving with such faeility among each other.

The pressure of fluids is exerted upwards and downwards, as well as sideways, not in proportion to their quantity, but in proportion to their perpendicular height.

To demonstrate that fluids press upwards as well as downwards, let A *b* B (plate iii. fig. 1,) be a long glass tube, filled with water near to its top; and C D a small tube open at both ends, and plunged into the water in the large one: If the immersion be quick, the water will rise in the small tube to a level with that in the great one. Hence it is obvious, that the water is pressed upward into the small tube, by the weight of what is in the large one: and as it only rises to an exact level, the pressure must be in proportion to the perpendicular height of the water without any regard to its quantity.

But if the small tube be taken out, and stopped at the upper end with the cork C, it will be full of air all below the cork; and on being plunged again to the bottom of the great tube, the water will rise in it only to the height E. This shews that air is a body, as it could not otherwise prevent the water from rising to the same height as it did before; and it also shews that air is a compressible body, for if it were not, it would be impossible for any water to enter into the tube.

Considering the pressure of fluids as equal in

all directions, you are to observe, that the sides of a vessel are as much pressed by the fluid in it, all around in any given ring of points, as the fluid below that ring is pressed by the weight of all that stands above it; from which we infer, that the pressure upon every point in the sides, immediately above the bottom, is equal to the pressure upon every point at the bottom. To illustrate this, my children, suppose a hole to be made at D (fig. 2,) in the side of the tube A B, near the bottom; and another hole of the same size in the bottom at C: Let water then be poured into the tube as long as you choose the holes should run, and have two vessels in readiness to receive the water thus ejected: You will then find by measuring the quantities, that they are equal; which demonstrates that the water ran with equal speed through both holes, and must consequently have sustained an equal pressure. For if another hole of the same size were made in the side of the tube at *f*, and if all three were permitted to run together, the quantity ejected from the orifice at *f* would be considerably less than that thrown out in the same time through either of the holes C or D.

If, in the same figure, the hole at C being stopped with a cork, a tube were turned up from the bottom into the shape D E; and water

were poured into the tube to the height A g, it would spout up in a jet E F G nearly as high as the surface A *g*; and this might be continued by pouring as much water into the tube as ran through the hole D. The reason why the jet does not rise quite so high as the surface of the water A g, is because it meets with a resistance in the open air; for if a tube were screwed upon the pipe at E, the fluid would rise in it to a level with that in the large tube.

Any quantity of a fluid, however small, may be made to balance and support any quantity, however great. This, being an assertion contrary to appearances, is called the *hydrostatic paradox*; but I shall endeavour to illustrate it to my children by experiment.

Let a small tube (fig. 3,) marked H D C, open throughout, and bended at B, be joined to the end of a large tube A I at *c d*, so that they may freely communicate with each other. Then if water be poured through a small-necked funnel into the small tube at H, it will flow through the joining of the tubes at *c d*, and rise up into the great tube; and if, when the water rises to any particular part, as A, in the great tube, you leave off pouring, the surface of the water will be precisely the same in both tubes; which proves that the small column of water in the little tube balances the large one in the greater.

If the small tube were bent in an oblique direction as G E F, the surface of the water would stand at F, that is, on the same level as it stands at A in the great tube.

This experiment may suffice to shew, that as the pressure of fluids is in exact proportion to their perpendicular heights, without any regard to their quantities, it appears, that whatever be the figure or size of vessels, provided they are of equal heights, and the areas of their bottoms are equal, the pressure of equal heights of water are equal upon the bottoms of these vessels, even though one should hold ten thousand times as much water as would fill the other. It is therefore plain that a pint of water may be made to support a hogshead; or, as I have before observed, that any quantity of a fluid, however small, may be made to balance any other quantity, however large.

The best machine ever invented for demonstrating the upward pressure of fluids is the hydrostatic bellows A (fig. 4,) which consists of two strong oval boards, about 16 inches broad, and 18 inches long, and is made to open and shut like a common bellows, but without valves: you must observe, however, that a pipe B is inserted into the side of the bellows. Now, if some water be poured into the pipe at C, it will run into the bellows, and separate the boards. Then

if three weights *b c d,* each weighing 100 pounds, be laid on the upper board, and more water be poured into the pipe B, the board will rise up with all the weights upon it; and if the pipe be kept full till the upper board of the bellows is raised to its full height, the water in the pipe will support all the weights, even though it should not weigh more than a quarter of a pound; nor will all this force be sufficient to force the water out at the top of the pipe.

The reason of this, my children, will be sufficiently obvious, when you recollect what I have previously said of the pressure of fluids of equal heights, without any regard to the quantities: For if a hole be made in the upper board, and a tube be inserted, the water will rise in the tube to a level with that in the pipe; and if properly supplied, it would rise as high in as many tubes as the board could contain holes. Now, supposing only one hole to be made in the board of an equal diameter with the bore of the pipe B, which contains a quarter of a pound of water; if a person were to put his finger upon the orifice, and the pipe were filled with water, his finger would be pressed upward with a force equal to a quarter of a pound; and as each part of the board whose area is equal to the area of the hole, must be pressed upward with an equal force, the sum of all

the pressures against an oval board 16 inches broad and 18 inches long, must amount to 300 pounds; and so much weight may consequently be raised and supported by a quarter of a pound of water in the pipe.

We must now attend to the pressure of fluids with regard to the motion of them through spouting pipes: and here, my children, you must observe, that the velocity with which water, or any other liquid, is ejected through a hole in the side or bottom of a vessel, is as the * square root of the distance of the orifice below the surface of the water. For, if I wish to make double the quantity of water flow through one hole as through another of the same size, I must place it four times the depth of the other below the surface, as knowing it will require four times the pressure of the other.

To render this perfectly familiar, let two pipes, C and *g*, (fig. 5,) of equal bores be fixed in the side of the vessel A B; the pipe *g* being four times as deep below the surface of the water in the vessel as the pipe C is. Then let a pint cup be placed at K, to receive the water that spouts from the pipe C, and a quart cup held at L, to catch

* The square root of any number is that which being multiplied by itself produces the same number. Thus the square root of 1 is 1; but of 4 it is 2, of 9 it is 3, &c. because 2 multiplied by 2 produces 4; and 3 multiplied by 3 produces 9.

the water ejected through the pipe *g*, and both will be filled at the same moment by the respective pipes.

Specific gravity is the relation that the weight of a magnitude of one kind of body, has to the weight of an equal magnitude of another kind of body.

There are three short rules which natural philosophers have given on this subject.

The first is, if two bodies be equal in density, and unequal in magnitude or volume, they will have their masses, their matter, or their weights, in a direct proportion to their magnitudes, that is, their weights will be like their volumes: if the magnitude of one body be double that of another, and the specific gravity of both be equal, the weight of the first will be double that of the second body.

The second rule is: if two bodies be unequal in density, but equal in magnitude, their weights will be in proportion to their densities; that is, if the density of the first be double that of the second, the weight of the first will be double that of the second.

The third rule is: when two bodies are unequal in density and magnitude, their weights will be, in a proportion, compounded or made up of their densities and their magnitudes; that is, you will not be able to know the respective

weight of each, but by multiplying their density by their magnitude. If the magnitude of one body be marked by the figure 2, and its density by the same number; and if the magnitude of another body be denoted by the figure 4, and its density by the same number, the weight of the first body will be as much less than the weight of the second body, as 2 multiplied by 2, that is 4, is less than 4 multiplied by 4, that is 16; now 4 is only the fourth part of 16; therefore, in the present instance, the weight of the first body will only be a fourth of the weight of the second body: for, when two bodies differ both in density and magnitude, their weights are in a compound proportion of their densities and volumes; and indeed this fact is proved by daily experience.

In this comparison of the weights of bodies, one alone is generally considered as the standard or the unit to which every other body is compared: and as pure rain-water is in all places pretty much the same, natural philosophers have chosen this fluid as their term of comparison.

It has been found by repeated experiments that a cubic foot of rain-water weighs $62\frac{1}{2}$ pounds avoirdupois; consequently $62\frac{1}{2}$ pounds divided by 1728 will be the weight of one cubic inch of rain-water.

A body immersed in a fluid will sink to the bottom, if it be heavier than its bulk of the fluid;

and if it be suspended therein, it will lose as much of what it weighed in air, as its bulk of the fluid weighs. Hence all bodies of equal bulks which would sink in fluids, lose equal weights when suspended therein, and unequal bodies lose in proportion to their bulks.

The hydrostatic balance (plate ii. fig. 6,) differs but little from a common balance; except that it has a hook at the bottom of one scale A, on which small weights may be hung by silk threads or horse-hairs; so that such bodies may be immersed in water, as in the vessel B, without wetting the scale from which they depend.

If you are desirous of ascertaining the specific gravity of different bodies by this instrument, you must weigh the body first in air, and afterwards in water, observing how much weight it loses by being weighed in water; and then if you divide the former weight by the loss sustained, the result will be its specific gravity compared with that of the water.

To render this still more plain, I shew you that this piece of silver weighs in air 318 grains: I now fasten it to the hook with a horse-hair, and it weighs in water 288 grains, which, subtracted from 318, leave 30, the weight it lost in water. Then by dividing 318 by 30, I find the quotient to be about $10\frac{1}{2}$: the specific gravity of the silver, therefore, is ten and a half times greater than that of water.

To ascertain the specific gravity of quicksilver, fragments of diamonds, &c. which cannot be suspended by threads, you must put a glass bucket (as fig. 7,) on the hook at the bottom of A, and counterpoise it by weights in the opposite scale. Then weigh the body carefully, and if you subtract the weight of the bucket, you will have the true weight of the body in the fluid.

But in order to find the specific gravity of those bodies which are lighter than water, as cork, wood, &c. you must adopt the following method:

Let an upright stud be fixed in a flat piece of brass, and in this stud let a small lever whose arms are of equal length turn upon a pin as an axis. The thread which hangs from the scale of the balance must then be tied to one end of the lever, and a thread from the body to be weighed tied to the other end. When this is done, put the lever into a vessel, and pour water upon it, so that the body to be weighed may float, and draw down the end of the balance from which it hangs; then put as much weight in the opposite scale as will raise that end of the balance, so as to pull the light body down into the water by means of the lever; and by this weight in the scale you will find how much the body is lighter than its bulk of water.

The following brief observations I also wish

you to notice, as they may assist you in answering her ladyship's questions :

The difference of weight or of density of two liquids is sufficient to separate their parts when mixed, if that effect be not hindered by more powerful causes.

Many fluids, though of different natures, weigh against each other in a proportion of their densities and their attitudes.

Two liquids of different densities balance each other, when, having both of them the same base, their heights above the horizon are in an inverse proportion with their specific gravities.

The air is a fluid which weighs, and exerts the pressure of its weight in every direction, like all other liquids.

A solid body wholly immersed in any fluid, is compressed on all sides round; and the pressure which it experiences is proportionable with its own depth, and the density of the fluid.

The weight that a solid body loses when immersed in a fluid, is equal to that of the volume of the fluid which it has displaced.

The knowledge of the specific gravities of bodies is of frequent and great use, in computing the weights of such bodies as are too heavy or too unwieldy, to have them discovered by any other means.

These few hints will be sufficient to throw a

light on the questions that Lady Caroline is now going to propose to you, and will enable you, I have no doubt, to give her very satisfaetory answers.

Lady Caroline.—Why, Mary, does a barge, or a bucket, sink the moment it springs a leak; that is, when a sudden aperture takes plaee?

Mary.—Because the substance or matter of whieh those vessels is made, is speeifically heavier than the fluid which supports them: if the water ean by any means introduce itself, and fill them, the whole together makes up a mass, of which the weight exeeeds that of an equal volume of water; and for this reason the vessel must sink and be lost.

Lady Caroline.—All porous and spongious bodies, Mary, when long exposed to the moisture or humidity of the air, become a great deal heavier than they were. What cause produees this effect?

Mary.—Bodies of that nature, such as wood, soft stones, the mould of the earth, and others, naturally imbibe every aqueous particle that touches them, by the addition of whieh foreign matter their weights are neeessarily inereased; but when the air becomes more dry, they lose that weight in the proportion in whieh they exhale their moisture.

Lady Caroline.—What is the reason, Frederic, that those people who sell by weight goods

equally susceptible of becoming moist or dry, such as tobacco, indigo, sugar, and others, are particularly careful to keep them in the coolest parts of their repositories?

Frederic.—I should imagine, Madam, that it is in order to prevent an evaporation, which might prove detrimental to their traffic. Besides the very considerable quantity of aqueous particles with which these bodies become charged in such cool places, is an effectual addition to their weight.

Lady Caroline.—The timber, William, allotted to the building of vessels, swims at first, when thrown into the wet-dock; but by degrees it sinks, and becomes at last hid beneath the surface of the water. Tell me how this may happen?

William.—In course of time I should imagine that the timber must be deprived of its salts, and other substances specifically lighter than the liquid which immediately takes their place; and then the liquid, made up both of wood and water, equals, and even surpasses, in weight, the liquid which surrounds it; for it is a well-known fact, that the constituent parts of the lightest wood are more heavy than water. Cork itself ceases to swim after having been long steeped, because then its parts disunite, and do not any more make up a volume, as usual, with much more void than solidity.

Lady Caroline.—How is it, Fanny, that hoar-frost, snow, and every other kind of watery congelation with which all trees and plants are so often covered, bear down the bodies they adhere to, and fatigue them much more than common rain-water does?

Fanny.—In general I have observed, that those kinds of congelations thicken much more round the smaller branches than round the trunk: the weight, therefore, not only of the humidity, but of every foreign little substance, that the frost fixes to the tree with this moisture, attacks it in its weaker parts, so that at last the tree itself is destroyed in its branches.

Lady Caroline.—There are in many countries, Edward, natural grottos and caverns containing vast quantities of stony concretions, which are formed drop by drop, and hang down from those subterraneous vaults, like so many icicles formed by a thaw, under the roofs of houses, or wherever there is a gradual melting of snow: What can be the cause of this phenomenon?

Edward.—Those stones to which people have given the name of *stalactites,* are originally liquid, like the water in which their parts are conveyed. The first drop which remains hanging from the vault, adheres to it no longer than is necessary to support its own weight; but in proportion as its moisture evaporates, it becomes solid, and able to bear the

weight of other sandy drops, which arrive at a similar situation; so that at last a very considerable mass hangs from the vault in spite of its own weight, for no other reason, than that it has become solid by the evaporation of the water, and the agglomeration of the little particles which now are fastened to each other, by the means of that one which originally clung to the vault.

This operation of nature is very closely imitated by chandlers in general. They thrid in a parallel manner the eyes of the wicks upon long slender rods, and plunge them repeatedly into trays of melted tallow; or sometimes pour from above the liquid wax all along the wick. This last mode is generally recurred to in making large wax tapers, designed to be broader at the bottom than at the top: for it is obvious, that the matter becoming cooler decreases in velocity towards the end of its fall; and great care is likewise taken not to employ it in too hot a state, that, at every immersion or pouring, the greater quantity of substance may adhere.

Lady Caroline.—How is it, Sophia, that a piece of ice of one pound weight does a great deal more harm when it falls, than an equal quantity of water?

Sophia.—When the water falls, the air, as it is a resisting medium, divides its parts; this division increases the surface of the water, and

very considerably retards the velocity of its fall; whereas the piece of ice, offering a smaller surface to the resisting air, preserves its rapidity, and by its impression being more suddenly made, exerts its power at once, and thereby does much more harm than the water.

This answer may be extended to an angular or pointed body, which is a great deal more dangerous in its fall, than if it had been flat: for its whole effort is re-united against one small spot; and, by a contrary reason, we are less in danger of being hurt, when we receive a cricket-ball, for instance, with hollow instead of extended hands.

Lady Caroline.—Why, Mary, do inclined bottles, or fresh-tapped barrels empty themselves?

Mary.—The liquor they contain presses them in every direction, and, of course, forces its way out; for the very same reason, I have heard it said, that a ship pierced by a cannon-ball, immediately leaks by her side, and will as infallibly sink, as if the shot had been in the very bottom of her keel; and the water will so much the more quickly rush in, as the sea is higher above the hole.

Lady Caroline.—Here, Elizabeth, is a cup with a very small hole at the bottom of it. How is it, that it becomes full, as I thus perpendicularly press it down in this bason of water?

Elizabeth.—The weight of the surrounding

columns of air presses on the liquid, so as to raise it upwards. Thus, to draw water from very deep wells, people sometimes make use of two buckets, tied to the ends of the same rope, which runs round a species of pulley, that turns in such a manner, as to let one bucket down while the other rises. They are filled at the bottom by means of a kind of pump-sucker, which opens to receive the water that presses upwards, but shuts when full, by the water that presses downwards.

Lady Caroline.—When water is intended to be carried by its own weight from one place to another, for the purposes of society; why, George, does the undertaking fail in succeeding, when the spaces are perfectly level?

George.—It is absolutely necessary that there be a slope, in order to surmount the resistance of friction; and it is for this reason, that in all aqueducts, in all conduit-tubes, and in all canals, where it is meant that the water should flow, workmen generally give the inclination or slope of one twenty-fourth part of an inch, to every fathom that they advance.

Lady Caroline.—Tell me, Kitty, how can water be made to ascend, even into our upper apartments, for domestic convenience?

Kitty.—The water that we receive in this extraordinary manner is previously preserved in reservoirs of higher situation, or runs over a

higher ground than those places to which it is intended to be conveyed; and this conveyance is effected by a continuity of sloping tubes, lodged under ground, and directed to their several destinations; as all water, therefore, endeavours to rise to a level with itself, it will forcibly mount up through the pipes of the several apartments, until it becomes at last equal to the height and level of the body of water from which it came.

Lady Caroline.—Why, Frederic, is it prejudicial to the owner of a pump, that the workmen should, through ignorance, make the pipes intended to convey the water too small?

Frederic.—The owner will receive a very small portion of that water to which he is entitled, on account of the great increase of friction; for this kind of resistance increases as the surfaces increase, and the internal surface of a small tube proportionably exceeds that of a large one.

Lady Caroline.—I have seen, William, when on board of a pleasure yacht, a very curious experiment tried, which I hope you will be able to explain. The sounding-lead you know, is a large leaden weight, tied to the end of a very long rope. The gentleman who shewed the experiment, took first a common cylindrical quart glass bottle, perfectly empty, and having corked it

with a cork secured by many folds of linen, and sealed round with sealing-wax, in as exact a manner as could be done, he tied it to the end of the sounding lead. The empty bottle, dragged down by the weight of the lead, went to the bottom of the sea, when we were at anchoring. He did the same thing with a round bottle, and an oval one; and when they were hauled in, I was extremely surprised, as well as the rest of the company, to see them all full of the most transparent water, and considerably more salt than the water on the surface of the sea. The sounding-lead had descended two hundred and twenty-five fathoms. Now, William, can you account for this?

William.—Every fathom that the bottle descended added new strata of water over it, and the pressure of so enormous a weight continuing incessantly to act upon it, with weight always increasing, forced through the very pores of the bottle, as well as through the wax and the cork, the acute and small particles of salt, which, from the pressure they are always in at so prodigious a depth, are urged by the surrounding particles and water, to rush in wherever there is less compression: now, the pores of the bottle and cork offer pores enough to such fine spicula, which, when entered, melt down into water, and soon fill the respective bottles, when

the altitude and base of the sea they were in, multiplied into each other, amounted to a strength equal to produce such an effect.

Lady Caroline.—How does water rise, Henry, in those pumps which act by a species of attraction?

Henry.—The external air presses down upon the water, and in proportion as the sucker, by being drawn upwards, exhausts the internal air of the tube, the external air impels the water after it.

Lady Caroline.—I saw, Henry, a curious experiment performed by your father a considerable number of years back, which I hope you will be able to account for. He filled a very small and long tube with a few pints of ale; this tube he placed on the bung-hole of a very large barrel, full of ale, and so placed in a copper trough that the liquor might not be lost to a group of his tenants, whom he meant to regale by the experiment. He no sooner placed the tube on the orifice, and poured the few pints in, but the large barrel instantly burst. Well, Henry?

Henry.—I should imagine, that when this small tube or column is placed upon the aperture of the barrel, and the pints poured in, it becomes one continued body with the barrel itself, and having the barrel for its base, the

tube acquires the same strength as if it were equally broad along its whole height: for as fluids increase in pressure by the increase of their altitude and base, you cannot augment one without communicating its weight to the other.

Lady Caroline.—I have here prepared two small kegs, equal in size, and both equally full of water. I now beg the favour of Sir Thomas to pull out those small bungs which cork up two apertures, exactly equal to each other, and when this shall have been effected, Elizabeth will be so good as to give us an account of what she observes?

Elizabeth.—Are those basons, Madam, equal in contents, which you have placed to receive the water in each keg?

Lady Caroline.—They are, Elizabeth.

Elizabeth.—I perceive then that the water of one of those kegs rushes out with much greater rapidity than the water of the other: and I perceive that one bason is almost full, while the other has received little more than half its contents. The reason of this must, I think, be, a circumstance which your Ladyship has not mentioned to us, and that is, that the hole of one keg is a great deal lower than that of the other: there must therefore be a much greater weight above the water that flows from the

lowest hole, than there is on the water that issues from the highest, on account of the greater length of the column.

It is for this reason that all *jets-d'eaux*, or water-spouts, rise and throw out in proportion of the heights of the reservoirs; and the elevation of the spout becomes less in the same proportion that its reservoir empties itself. Hence it likewise follows, that all vessels of uniform capacities, such as cylinders, prisms, and others, never empty themselves equally in equal times, when the flowing of the liquid takes place at the bottom of the vessel. The respective quantities which flow during every minute of time, diminish in the exact proportion of the descent of the surface of the flowing liquor. For this reason, I should think that the basons of public reservoirs should always be kept equally full, that individuals may not be wronged in their just allowances.

In the time of the vintage, when the wine-tubs are broached, the issuing wine spouts farther, and in much greater quantity at first than towards the middle or the end of its flowing, for the above-mentioned reason, of the altitude of the liquid diminishing, the pressure decreasing, and the ceasing of the fermentation of the spirit.

Lady Caroline.—Why, Kitty, during violent

and long rains, do we see large brooks, which had no previous existence?

Kitty.—I suppose the same reason takes place in this instance. There are a great many springs whose surfaces lie much beneath the surface of the earth, and never make their appearance until long rains have raised the column of their waters, not only to a level with the earth, but have made them overflow, so as to feed for a space of time the brooks they thus give rise to.

Lady Caroline.—I take this small bottle, Mary, full of lavender-water, and un-corking it, I lay it on its side. What do you observe?

Mary.—I perceive that the lavender-water has been a long time in coming out, but I now see it flow with increasing swiftness: I believe the reason of this may be, that the air at first took some time before it could insinuate itself into the neck of the bottle, and by that means proved a temporary obstacle to the water's running out; but having once procured a passage, it forces its way on, and, by the elasticity of its spring, urges the water more rapidly.

Lady Caroline.—The air, Fanny, presses much more forcibly in valleys than on mountains, and water rises to a much greater height in the first than on the last. What is the reason of this?

Fanny.—The same as before; the pressure

and the elevation are both owing to a longer column of air. I should therefore think, that before clock-work had arrived at its present perfection, the instruments which were used for the measuring of time must have been very imperfect. The ancient *clepsydra* and the modern hour-glass, being only vessels of which one part empties itself in a certain time of its water, or of its sand into another, can never give a division of time to be trusted to; for, generally speaking, the velocity of flowing substances depends not only on the perpendicular height of the fluid, but also on the quantity of friction, on the degree of fluidity, and on the proportion of density, all of which are very variable, and extremely difficult to be estimated.

Lady Caroline.—I have here a crooked glass tube, something, you see, like a pair of spring tea-tongs, with this difference, that one of the arms is ten times wider than the other. Both the arms of the tube communicate with each other, and having now poured this water into one, you see it rise in the other to a height exactly equal; that is, though one arm holds ten times the water of the other, yet the smaller balances the greater. Account for this, George.

George.—All fluids of the same kind which have in any way immediate communication with each other, act against each other precisely

in the proportion of their heights, as Sir Thomas has kindly shewn us. By being more or less wide, their reciprocal power is in sense diminished or increased, because bodies of this nature act against each other, just in the degree they are pressed. Now the pressure they experience is accurately and solely in proportion to their perpendicular heights.

Lady Caroline.—I take this other crooked tube, one of the arms of which is equally wide as the large arm of the other; but this other arm, you may perceive, is so minute that the width of its opening is but the thirty-sixth part of an inch. I pour water in the large arm, but you may now see, that having entered the small arm, it ceases to be level. Is not this against the general rule, Frederic?

Frederic.—I do not see how the general rule can in this instance take place; for the internal space of the smaller tube is so extremely small, that I have heard it called by Sir Thomas the *capillary* tube, from the resemblance of its aperture to a hair, in Latin termed *capilla.* Now the very small portion of water contained in this capillary tube, having more surface to contend against, and being more impeded and supported by the irregularities of the almost contiguous sides of so narrow a tube, has scarcely any force left, and must stand above the level, to be able

to counterpoise the water of the large arm. This exception to the general rule, therefore, proceeds from the extreme tenuity of the tube, and not from the capillary column of the contained liquid.

Lady Caroline.—Why, Sophia, does compressed water, such as that contained in the narrow passages that lead into or out of mill-dams, accelerate its motion?

Sophia.—The lateral parts which meet the obstacle in the contracted sides of the little channel, are at the moment of their passage more compressed by the water that follows, and incessantly pours on them. Being thus urged on and squeezed, they make a greater impression on the parts which flow directly and freely in the centre of the strait; and the resistance of these last parts is never felt, as there is an open passage for them to proceed. In this situation more water must flow in equal times, and therefore in those narrow necks the increase of water will ever produce an increase of velocity; this may be exemplified by the slow motion of a river in the larger parts of its bed, and its extreme velocity when it rushes through the arches of a bridge: and I have heard you say, Madam, that if the orifice of a common squirt be ten times narrower than its body, it will acquire a tenfold velocity in the water it sends forth.

Lady Caroline.—As you have mentioned the squirt, Sophia, I beg you would tell me by what means the water mounts into it?

Sophia.—When I place the orifice of the squirt in water, and draw the sucker up, the water next the mouth loses the support of the air which I have extracted; it therefore becomes lighter, and must consequently yield to the heavier parts which surround it, and heave it upwards. In general, all the weaker parts of any liquid ascend, impelled as they are by the heavier and stronger parts which raise them.

Liquids of different kinds and of different weights never are level with each other, because the heaviest air must descend, and raise up and support the lighter. This is the reason why we so often see little balls of air flowing rapidly up after each other in a decanter, where the water has been long kept; for the air that has gradually crept into it, being put in motion, flies to the surface to regain its natural situation, by means of the water's density.

Lady Caroline.—I pour this wine and water into a glass. It is well known that the water is heavier than the wine, yet you see they both mix. How does this happen, Mary?

Mary.—Your Ladyship poured the water on the wine, and then they both immediately mixed; but had you gently poured the wine on the water, there would not have been a mixture

without shaking them; but the true reason of their mixing is that in their fall they both acquire a velocity strong enough to divide their particles, to trouble their balance, and to introduce themselves into each other's pores, until friction exhausts their motion, and renders them unable to disentagle themselves.

Lady Caroline.—I avail myself, Mary, of your ingenious hint of gently pouring the wine on the water, and now pour the water first into this glass; the consequence is, that the wine still goes to the bottom, and yet I have not shook them. How does this agree with your answer, Mary?

Mary.—If your Ladyship will suffer the wine to recover itself, and if you have not been over-hasty in the pouring of it out, I fancy you will soon see it assert its superiority over the water: and I think I already see the little ruby streaks re-ascending and getting the better of the precipitancy of your hand.

Sir Thomas.—You are perfectly right, my sweet girl; the wine has already got to the top, and nothing but loss of balance in the hand that pours it in, could make it quit the surface: but that you may always be sure of succeeding in this little experiment, I will beg the favour of Lady Caroline to cut a thin slice of stale bread, and lay it on the surface of a broad finger-glass,

half full of water, and then pour gently on it as much wine as the finger-glass will hold.

Her Ladyship, I see, has succeeded. Now, Mary, what do you observe?

Mary.—I observe that the wine is now wholly uppermost, and I think I can assign a reason for it.

The motion it had acquired is by this stratagem of yours, Sir, almost instantaneously arrested; and if any motion should remain, it becomes totally lost by filtering through the pores of the bread: it will therefore by its specific lightness remain in that superior situation.

Lady Caroline.—Let us see, William, if you can give as ingenious an account of what I am going to shew you, as Mary has given of the last experiment. I have here a tumbler full of new milk, which I have purposely set aside, that I might have your observations on it, and the reason of what you observe?

William.—I observe nothing but a circumstance that daily happens; I see a very rich layer of cream on the top, made conspicuous by the yellowness of its colour, while the pure white milk lies under to support it. The reason of which I take to be this; the particles of the cream are of a more adipous or greasy nature, than those of the milk, and consequently less compact: they cannot be less com-

pact without containing less matter; they cannot contain less matter without being less dense; and if they are less dense, they cannot be so specifically heavy as the milk. The milk, therefore, must tend to the bottom, and the cream swim. Thus all fat, animal, vegetable, and mineral substances, when shaken with water, mix in it for a time; but the particles being infinitely less dense, or specifically heavy, they soon disengage themselves and rise to the top; and the general method recurred to by people employed in these matters, is, to allow them time to extricate themselves for the purpose of separating them.

Lady Caroline.—We frequently see on the surfaces of stagnant pools, rich streaks of various colours, which, in certain directions, emulate the tints of the rainbow. What is the reason of this, Henry?

Henry.—The earth beneath the pool may be either bituminous, or sulphureous, or both. In this case, the fat particles, being washed away from the bottom, rise to the top through their specific lightness; and hence they reflect the rays of light as they form a continuity of surface, and perform in a manner the offices of mirrors. Waters in which clothes are washed, and ditches in which the carcases of dead animals are thrown, are likewise subject to have their surfaces covered with this spume.

Sir Thomas.—Tell me, Edward, why does a fat animal excel a meagre one in the act of swimming?

Edward.—A drop of oil, or a particle of any kind of fat substance, always lies on the surface of water: a larger quantity, therefore, of the same matter must have the same effect, since substances of that kind are less heavy than others. This reason comprehends another, which is, that adipous bodies have more vacuities and hollows, and partake more of the nature of bladders, the very essence of which seems to be the opposite of descent or sinking. On this principle, a hog, or a bullock, incur much less risk of drowning, when thrown into the water, than a cat or a ferret.

Lady Caroline.—How does it happen, Kitty, that considering the impalpability of the air, and the palpability of straws, bits of paper, and the grosser kinds of exhalations, such bodies, notwithstanding, mount up to considerable heights in the air, and remain there for a long space of time?

Kitty.—Their rising into the air is owing to the motion of the air itself, when their weights are specifically heavier, or even equal; but when their particles are so divided as to spread through a large portion of the air, they then are lighter, and will rise and remain in the air

till such time as they dissolve into rain, or are exhausted by the heat of the sun.

Lady Caroline.—This small phial of oil has been for a long time laid aside, and has of course collected a vast quantity of aërial particles: I now shake it, and the globules of air all mount to the top. What is the reason of this, Frederic?

Frederic.—The air, Madam, is lighter than the oil, as oil is lighter than water, as water is lighter than mercury; and so on.

Lady Caroline.—You see, Elizabeth, I have here beat up together a little oil and water, and have suffered the air to mix with them; the consequence is, that they all three have lost their fluidity. I now again whip a little cream with this white of an egg, and you may easily perceive that they too cease to be fluid. What can be the reason of this?

Elizabeth.—The friction increasing in proportion as the surfaces are multiplied, the mixed liquors may be divided into so small portions, that they may touch each other in too many points, and the difference of their weights, which can alone disunite them, may not equal the friction, or the difficulty they meet with of disengaging from each other.

It is for this reason that oil and wine, when well beat up together, become ointment; and

that the white of an egg, cream, &c. swell into a motionless froth: for the air is so extremely divided, and its mixture with those liquids is so very intimate, that its specific lightness is not sufficient to loosen it from them.

To these reasons I can add two other causes, which render the separation of the parts so difficult; one is, the viscosity, which is greater or less in one substance than in another, but from which no substanee is exempt; the other is, the sympathy, or rather analogy, which is frequently found between two liquids, and which probably consists in an adaptation of parts, a likeness of magnitude, and a fitness of figure. Thus spirit of wine once mixed with water can by no art be ever again separated from it, while oil of turpentine, which is not a great deal lighter, suffers no diffieulty in being drawn from the water it was mixed with.

Lady Caroline.—Here is a little but very curious glass instrument, George; it consists of a small tube of glass, above which there is a speeies of cup, and the base, you see, is a kind of phial of the same matter as the tube. I now fill this phial with red wine; and then I fill the cup and the tube above it with water, and desire you will not only tell me your observations, but aceount for them.

George.—I observe a delicate film of the wine

raise itself off the surface of the phial, form into a point, direct itself in the shape of a column to the mouth of the cup, and continue its progress through the water; while at the very same instant of time, an equally small thread of water descends from the cup into the phial; and both the column of the wine and the thread of the water continue, the one to mount, and the other to descend, in a spiral motion, until every drop of the water shall have fallen into the phial, and every particle of the wine ascended into the cup.

The reason of all this I scarcely need mention after what has been already said by my sister Mary. I can only add to her account in this instance, that the water, being the heavier of the two bodies, and placed in the uppermost part of the vessel, cannot have its exertion of descent made otherwise known, than by its forcing the wine to appear first to move upwards.

Lady Caroline.—You alluded, George, to your sister Mary's answer; but how will that, or your own answer, account for this? the two liquids in the instance of your sister Mary's experiment, on their being poured on each other, mixed, but in this case no mixture takes place.

George.—In this vessel the water poured into the cup gently descends upon the wine, not by a manual pouring, but by the smallest

of tubes. It is no otherwise admitted but by the slowest descent of its own weight, without any velocity acquired from a fall. Hence the visible tranquillity betwixt the ascending wine and the descending water; they have neither of them motion enough to divide or embarrass each other, and of course cannot mix.

Lady Caroline.—I take this inverted siphon, and pour mercury into one arm of it, until it rise in each arm to one half of a graduation. I now pour this coloured water upon it; and the consequence is, that when the surface of the coloured water has risen to the fourteenth graduation, the mercury rises just one graduation higher in one arm than in the other. Account for this, Kitty.

Kitty.—The mercury loaded on one side by the column of water, rises on the other side, in order to balance the liquid which presses it; as soon as it ceases mounting, its height above its own level is equal to the fourteenth part of that of the water; and I have heard Sir Thomas say, that the weight of water is to that of mercury, as 1 is to 14; it is therefore very evident that the heights of these two balanced fluids are reciprocally proportionable to their densities, for as the mercury is fourteen times as heavy as the water, so the water is fourteen times as high as the mercury.

Lady Caroline.—How does it happen, William, that our bodies never feel the immense weight of the air upon them?

William.—From the very moment of our birth we are accustomed to its pressure. This pressure is equal, uniform, and continual, and affects the whole extent of our bodies at once; so that one part feels no more pressure than another: now, feeling is nothing else but a way of judging of our present situation, when compared to another preceding situation: but if our situation has never been altered, the sensation of the pressure can never have been interrupted, and therefore is, in fact, no sensation at all.

Lady Caroline.—I take this glass tube, stopped at one end, and of about three feet in length; I pour mercury into it; now that the tube is entirely full, I place my finger on its orifice to stop it, and after having turned it upside down, I convey that end which is stopped by my finger into a vessel which likewise contains mercury, and I now take away my finger from the orifice. The tube now plunged into the other mercury by the open end, partly empties itself into the vessel; but there still remains a column of mercury of about twenty-seven inches in height. Can you explain this, Elizabeth?

Elizabeth.—The air being a matter, or sub

stance, has, like all other bodies, a tendency towards the center of the earth. A heavy body acts by its weight against every thing that is opposed to its fall, or becomes a base to it: thus, when a column of air reposes upon any body, it compresses it with all the strength of its weight. Now the surface of the mercury in the other vessel is, in your experiment, Madam, the base of a column of air; it must therefore be pressed by its weight. When your Ladyship applied a tube to a spot of this pressed surface, the column of mercury the tube contained being heavier than the column of air that immediately corresponds to its base, sinks, until its diminished elevation places its weight in balance with the pressure exerted on all the similar parts of the surface of the mercury in which the tube is plunged.

Lady Caroline.—I now make a small aperture in the uppermost and closed end of the tube, and I perceive that the mercury immediately descends. What is the reason of this, Henry?

Henry.—The air by this means enters through the small aperture you made, and acts upon the mercury so as to destroy the effort which the other part of the air made upon the mercury contained in the vessel: thus the column of mercury in the tube, being placed betwixt two

equal pressures, must fall to its own level through its own weight.

Lady Caroline.—I take this other tube, Fanny, open at both ends, and placing one end of it in this vessel full of coloured water, I suck up the air which is in the tube; and the water immediately ascends and fills it. How do you account for this?

Fanny.—The water, unloaded of the weight of the air contained in the tube, obeys the weight of the column of air which presses the water in the vessel.

Lady Caroline.—In this other vessel full of mercury, I dip the end of a tube of thirty inches length, but not more than one twelfth of an inch in width. I suck the air out from the tube, and the mercury rises up twenty-seven inches, and though I should continue to suck, the mercury will rise no higher. Can you give me a reason for this, Mary?

Mary.—As the mercury is a great deal heavier than the water, the weight of the external air which helps to raise it, is balanced by a shorter column. Had there been any other fluid more heavy than the mercury, we should have certainly seen it remain at a point still lower. In pumps where suckers are employed, the water only mounts to thirty-two feet; because as the weight of the atmosphere is limited,

a column of air does not weigh more than a column of water of thirty-two feet, though the column of air be vastly higher. Now mercury ascends only to the height of twenty-seven inches; for its weight being to that of the water, as one is to fourteen; the column of air, in raising up the mercury to twenty-seven inches, exerts itself as much as it does in raising the water to thirty-one, or thirty-two feet. For the mercury weighing fourteen times more than the water, if it is at the height of twenty-seven inches, you must, in order to compare this elevation to that of the water, reckon twenty-seven times fourteen inches, which on calculation you will find to be thirty-one feet and a half.

Lady Caroline.—How is it, Edward, that the greater number of long-billed birds, such as herons, storks, and woodcocks, as well as almost all quadrupeds, such as horses, cows, stags, &c. can when they please raise up water in their stomachs?

Edward.—All these animals may be more properly said to suck than to drink, and the act of sucking is in fact nothing more than rarefying the internal air by dilating the capacities which contain it, to give room to the pressure of the atmosphere. The chest in raising itself, somewhat in the way of opening bellows, pre-

pares a new vacuity, to fill which the external air rushes in, an act which we call respiration; but if the mouth be moist with, or full of water, though this last fluid were beneath the stomach where the void is made, it is carried thither by the weight of air with which it is always loaded.

Lady Caroline.—Why is it so very diffieult, Sophia, to draw up the sucker of a syringe, the orifice of which is either entirely stopped, or in a vessel void of air?

Sophia.—While the sucker, pressed externally by a column of air, is likewise pressed back internally by another column of water, supported by an inferior column of air, it is in balance betwixt two equal powers; and to move it, it is only necessary to overpower its friction. When, however, the inferior supporting column of air is removed, we can no more draw the sucker upwards, without raising the whole column of air that presses against it: and this column is a cylinder, the height of which is the atmosphere itself, and the base the top of the sucker.

Lady Caroline.—Here is a small pair of bellows, Frederic, of which I have shut up all the apertures. Take them, and tell me what you experience?

Frederic.—It is with a great deal of difficulty that I can move them. They appear to be in

the same situation as the sucker in the syringe; for as there is no internal air to act against the external air, there can be no balance.

I imagine it is for the same reason that the breast of an animal can no longer expand itself as usual in the act of respiration, when the admittance of air is impeded. And it is the opinion of all able anatomists, that drowned animals have died, not through the quantity of water they have swallowed, but through the interruption of that motion which respiration requires.

Lady Caroline.—I fill this tumbler with water, and cover it with a paper that will closely touch its rim all round. I place my hand upon it, and then turn the glass upside down upon my hand: I now take my hand away, and you notwithstanding see that the water remains unmoved in the tumbler, and the paper adheres as close to it as if the tumbler were placed upright. Is there any reason, George, you can assign for this?

George.—The water contained in the tumbler cannot descend, but by overpowering the columns of air betwixt it and the floor; nor can it be removed sideways, as it is propped on all sides round by the atmosphere itself, which has a strength of bearing up a mass of water of thirty-two feet height. Thus the resistance

of the column beneath the water in the glass is a great deal more than sufficient to keep it from falling. The use of the paper in this experiment is only to hinder the division or mixture of the two fluids; for their weights are so very different, that they could not be otherwise hindered from falling into each other.

Sir Thomas.—I once saw, when abroad, Kitty, an experiment of a singular nature, which I hope you will be able to account for. A long tube, communicated at one end with about a dozen smaller ones. The ends of each of these tubes terminated in as many bladders; in the middle of the large tube there was a kind of key, which could open or stop up the passage of the tube; this was the apparatus, but the occasion of its invention was the following:—

Two young men of the first fashion in Italy, disputed respecting the strength of the Swiss who guarded their gates; and in the altercation one of them laid a wager, that the son of his Swiss, who was only eight years old, could display more bodily strength than the Swiss of the other nobleman.

A day having been appointed for the trial, a large beam was placed across the small tubes of the instrument I have already mentioned. It was then proposed to the Swiss to raise that beam, and simply remove it from the tubes;

but every exertion of his strength was put forth in vain, he could not so much as give it an appearance of motion. The child was then called, and, having received his instructions, desired every body should withdraw to some distance from the beam; he then blew into the tube with all his might, and when tired, turned the key or cock, that the air might not return back, and this he continued for a while to the great amusement of his master's opponent; at length, however, he so effectually filled the bladders with air, that the beam rose of its own accord, and rolled with great noise from off the tubes.

Kitty.—The breath of the child, I imagine, compressed and gave a new spring to the air contained in the large tube, from which the air in the smaller tubes and in the bladders received a gradual and growing pressure; this successive excess of spring or elasticity, exalted by the heat of the child's breath, distended the bladder so violently, that the imprisoned air, becoming at last equal in strength to the weight of the beam, communicated a commencement of motion to it, which the weight of the beam itself completed, by adding power enough to the spring, through pressure, to force it at length entirely from its situation.

Lady Caroline.—Why does a heavy body, William, weigh less in the hand of a person

who holds it in a heavy fluid, than if the same person held it in a fluid of less density?

William.—All bodies are supported in fluids, in the exact proportion of the weight of those fluids. Thus, if I take a body that weighs ten pounds in the air, and plunge it into water of an equal volume with itself, and which perhaps weighs two pounds, my hand will then have only to support eight pounds weight.

Sir Thomas.—Do you recollect, Elizabeth, what may be the weight of the column of air which corresponds to the human body?

Elizabeth.—It has been discovered that a middling-sized person corresponds to a mass of air of upwards of twenty thousand pounds weight. But a fish at the bottom of a river or of a lake has not only the pressure of the air, but that of the water to support; so that if it be thirty-two feet deep, it is loaded with twice the weight of the atmosphere. What then must the pressure be on the body of an animal at the bottom of the ocean? These enormous weights, however, continually applied to the surfaces of their bodies, do not destroy them, because they are internally supported by the spring of the same fluid that surrounds them: we breathe the same air internally by which we are externally compressed, and fish are in the same situation as we are with regard to the wa-

ter; for if they breathe air with water, this air, before it passes into their bodies, is in balance by its spring with the pressure of the fluid with which it is charged. The motion of the breast, in the time of breathing, is only free in as much as there is an equilibrium betwixt the external and internal air. Whatever accident renders the last weaker or stronger, adds to the difficulty of respiration. In a word, neither the weight of the air, nor that of the water, destroys the diver who plunges to the bottom of the sea, because he is equally pressed on all sides round, and because the internal balances the external air, and his ribs form a series of arches. It must, however, be remarked, that many divers who have been sent down under water in large bells full of air, have generally been obliged to be drawn up, their noses and ears running with blood. The reason of this is, that it is not sufficient that the diver has air conveyed down with him; it is also necessary that the air preserve the usual thickness he was accustomed to; and I do not think this can ever be practicable, considering the vast pressure of so immense a volume of water.

Sir Thomas.—When fishermen have thrown their net to great advantage, how comes it, Henry, that they are not afaid of breaking it when they draw it from the water into the air?

Henry.—Immersion always reduces bodies to a respective weight, much less than their absolute one. Thus it sometimes happens, that a man of one hundred and thirty pounds weight on land, is not above one or two pounds in the water. Hence a twig, or even a few blades of grass on a bank, may sometimes save a drowning person, whereas a person falling out of a window would pull the weight of a very considerable relief after him.

Lady Caroline.—I throw this wax ball into a bason of cold water, and it swims. I now heat the water over this chafing-dish, the ball then sinks, but the heat increases, and the ball mounts again. Can you give any reason for this, Fanny?

Fanny.—It swims at first, because it is less heavy than cold water; it then sinks, because it becomes heavier than an equal volume of water rarefied by heat. It afterwards mounts again, because, being itself now rarefied by the still increasing heat, which penetrates and dilates the air that it contains, it becomes lighter than an equal volume of water.

Lady Caroline.—How do fish, Mary, sometimes remain suspended and motionless? and how do they go up and down the water with such freedom?

Mary.—They have in their bodies a bladder,

which they fill with air when instinct prompts them to become more light, and which they empty when they mean to become heavier: these vicissitudes of lightness and gravity are aided by the strokes of their tail against the resisting fluid.

Lady Caroline.—Why, Edward, do drowning animals descend at first to the bottom of the water?

Edward.—Because their bodies are heavier than the volume of the water in which they fall.

Lady Caroline.—Why do we afterwards see the drowned animal on the surface of the water? And why are these appearances sometimes so very frequent? Tell me, Sophia.

Sophia.—Because their carcases become alternately lighter and heavier than the volume of water to which they correspond; the body descends at first into the water, because it is heavier; it then re-ascends, beause the dilatation of the internal air gives more volume to the body; it then at last re-plunges, by the bursting of the membranes which contained that air, and by means of which the body was made to swim.

Sir Thomas.—How, Frederic, is the act of swimming accounted for?

Frederic.—The swimmer raises the water at his sides by the motion of his arms and legs,

the neighbouring columns of water become by this means higher: being thus made longer, they weigh more, since all columns of water weigh in proportion to their height. The great quantity of air which the swimmer likewise inhales, assists him considerably in this exertion, by diminishing his respective weight.

Sir Thomas.—And pray, Frederic, why do swimmers sometimes use bladders under their arms?

Frederic.—To increase the volume of their body, and thereby procure more columns of water to support them.

Sir Thomas.—Since we are upon this subject, Frederic, I shall ask another question. How does a diver re-ascend after touching the very bottom of the sea?

Frederic.—His respective weight in such an immense body of water is much lessened; he has nothing to do but to strike the bottom perpendicularly with his foot, to procure a spring; the collateral columns of water will then urge him upwards with great velocity.

Lady Caroline.—How is it, George, that a large vessel at sea sails with the utmost security, whereas, as I have heard it said, it would sink on a leak of fresh water?

George.—Salt water is much heavier than fresh water, and therefore can support a much

greater weight; for it is well known that all floating bodies sink more or less, according to the density of the fluid they move in.

Lady Caroline.—I have heard much talk of the floating islands, Kitty. Can a motion of this nature happen?

Kitty.—I think it may; water may in process of time undermine any mould, and the mass of earth may be kept close together by its being of a light nature, and interwoven in its parts by immense quantities of roots and other ligatures.

Lady Caroline.—How does it happen, Henry, that less water is requisite in order to support a vessel in a strait, than in the wide and spacious ocean?

Henry.—In the ocean, water expands itself into a larger circle, and rises to a lesser height. In a more confined place, water corresponds to a less width, and rises to a greater altitude. Now water, having a great weight, counterbalances and supports the ship precisely in the proportion of its exaltation: hence, the more narrow a harbour is, the less depth of water is required.

Lady Caroline.—Why, William, do fluids ascend in capillary tubes?

William.—The unequal pressure of whatever fluid is probably the fundamental point of the explanation of the ascension of the fluids in

capillary tubes; but the adherence or natural viscosity of all liquors, the size and figure of their parts, and perhaps a certain motion which belongs to them, are so many means which nature may have employed for these kinds of effects, and as so many objects which we ought to consider in our researches.

Here Sir Thomas interrupted William, saying, that capillary tubes are so called on account of their minuteness. They may be made of glass, or any other matter fit for containing water. They take this name, without doubt, from the resemblance that their apertures have to a hair, which we commonly look on as small canals, hollow throughout the whole length, and capable of transmitting some certain species of fluids. However, the diameter of capillary tubes may be equal to two-twelfths, and even two-twelfths and a half, of an inch.

Lady Caroline.—We often find a heap of sand, a soft stone, or an upright billet, moistened even to the top, although these bodies may not be an inch in water. What is the cause of this, Frederic?

Frederic.—As these bodies are porous, the water finds in them minute channels through which it ascends, as it would do in small tubes of glass; and to improve still farther this idea, because in a channel extremely polished and

very strait, the liquor opposing all its weight to the cause which elevates it, in lieu of passing through the winding passages, which are offered to it by the internal part of a solid body, it finds here and there a resting place: whence it may happen that it sets off by repeated springs, and perhaps with fresh force.

Lady Caroline.—Why, Mary, do the waters, and in general all bodies, evaporate considerably less in moist and calm weather, than when it blows a dry wind?

Mary.—Because a capillary tube which supports a column of liquor, like a sponge full of water, cannot draw up any more; in the same manner the air, being too much loaded, raises vapours no longer. In moist weather, the air is a charged sponge; in a dry wind it is an empty sponge, and which is constantly renovated upon the same surfaces.

Lady Caroline.—What is it, Fanny, that causes the vapours to fall in rain?

Fanny.—It is a degree of cold which condenses the part of the atmosphere where those vapours reign, and which drawing together the particles of water, unites them into drops too heavy to be supported by an equal volume of air; then the condensed air is a sponge compressible. This compression may be attributed not only to the chilness which may be the usual

cause, but likewise to the winds, by which the clouds are squeezed together, that is, the parts of the air most loaded with water; and in fact, the rain, particularly that of a storm, always falls by sudden gushes, like the expression of a spongious body full of water.

Lady Caroline.—How, Edward, does the sap of a tree pass from the roots to the trunk, and from the trunk to the branches?

Edward.—We may consider its course as so many small capillary channels, or as a continuity of spongious bodies, by which it is conveyed from the roots to the top of the tree, and more or less copiously, according to the actual state of the different parts which receive the sap.

Lady Caroline.—How, George, does every tree in a garden receive the nutriment which nature has prepared for it? And why does not the apple-tree take that which is adapted to the vine, or the myrtle, the jassmine, or the honey-suckle?

George.—If it be true, that the channels which convey the sap perform the office of capillary tubes, there an example presents itself, which may be regarded as a coarse imitation of nature concerning the object before us. If we put into a vase two liquors very different from each other, as oil and wine, and dip the two ends of a piece of list, one into the wine, the other into the oil, both will act like a

sponge; but the first will suck up the wine alone, and the last only the oil. All bodies of this kind are fit for drawing up fluids, but they load themselves with one rather than another, according to the analogy it has with those liquors. This analogy must undoubtedly consist in the form, the size, the disposition of parts, &c. Each species of plant probably does something of the like nature, and for the same reasons.

Lady Caroline.—You have answered, my dear son, like a lad of genius; however, I must remind you of a remark which you forgot to mention, that the ends of the list should, previously to their being put into the oil and wine, be daubed, one with oil and the other end with wine, or otherwise they might both at once absorb the oil, and leave the wine untouched.—Why, Kitty, does an angular or pointed body wound us more in falling upon us than a flat body?

Kitty.—Because its effort is wholly exerted upon one small spot, and by a contrary reason we risk less being hurt when we hold our hand hollow to receive a bowl than when we extend it.

Lady Caroline.—I suppose there is a great deal more subtile air within one body than in another; the consequence will be, that this last body will be less hard. What is the reason of this, Henry?

Henry.—Because then the solid parts of

which it consists touch each other by less surfaces, and the pressure from without is better supported by that which the fluid transmits inwardly. When wax, for instance, sensibly softens, it is that the subtle air with which it is peneirated, dilated by the heat, dilates in the same manner the space that it occupies; and as these spaces cannot increase but by removing the solid parts of those which surround them, the contact of these last becomes more rarefied, their junction less exact, and their coherence weaker.

Lady Caroline.—In some determinate cases, two liquors take all on a sudden a consistency greater or less, although we are not able to observe any degree of sensible refrigeration. Tell me if you understand this, William?

William.—This effect I have heard Sir Thomas call *coagulation*, and it may be explained by supposing the parts of such different configurations, as to reciprocally embarrass each other; and that they put an end between themselves to that mobility, in which principally consists the state of liquidity. The most beautiful coagulation is that which is made with oil of lime and the oil of tartar. When a person stirs this mixture a little, it becomes a white mass, capable of receiving any form, and hardening itself like wax.

Some people, likewise, coagulate a urinous, volatile, and a very subtile spirit, with the spirit of well-rectified wine; the white of an egg and the spirit of salt; blood and aqua vitæ, or brandy.

This last experiment demonstrates the importance of using spirituous liquors with caution, since they have the power of adulterating and stopping the fluidity of the blood.

Lady Caroline.—This glass jar (plate iii. fig. 8.) you see is filled with clear water, and closed at its mouth, by a moistened piece of bladder. You also perceive three little hollow images marked C, D, and E. Each of these is about the same specific gravity with the surrounding water, and has a hole in its foot. The effects of this invention now follow:

You perceive that before I touch the jar, the images all float near the surface; but when I press the bladder with my finger they all begin to descend, though they do not all sink to the same depth, for the image E remains at the bottom of the jar, while D stands about midway, and C appears to have sunk but a little below the surface of the fluid.

In the second place, if I press with less force, or if I cease to press, the images immediately re-ascend.

In the third place, if I moderate the pressure,

when the figures are descending, they stop at the very spot in which I choose to keep them.

In the fourth place, if I press the bladder, and at the same time whirl the glass around, each little figure plays the whirligig about its own axis.

These effects are the same when the bottle is turned upside down, and when that pressure is made from the lower part to the higher: thus, one may give it an air of mystery, by arranging many tubes in a frame, and making the necessary pressure on their orifices, in a manner hidden from the eyes of the spectators, with levers sending them back, or with strings hidden in the depth of the wood, or otherwise. Can you, Elizabeth, explain these effects?

Elizabeth.—The water is either not compressed, or is compressed with great difficulty. The air, on the contrary, is a flexible fluid, which may be compressed with the greatest facility. The little hollow figures which are here inclosed, are therefore full of a compressible matter, and environed with another that is not. When I press with my finger upon the bladder, I press all the mass of water which is in the bottle; the column which corresponds to the small hole in each figure, which your Ladyship has mentioned, not being able to re-enter upon itself, on account of its inflexibility,

carries all the effort that it receives from the pressure against the air which is in the figure: and as this fluid allows itself to be compressed and squeezed into a smaller space, it yields to the water a part of that which it occupies; then the figure is more weighty than it was, for we must look upon it as a composition of enamel; of air more condensed; and of a little water which it has received. If the whole, together, be more heavy than the correspondent volume of water, it goes to the bottom; it, on the contrary, re-ascends when it is lighter, that is, when a less pressure impels less water into the figure, or when I allow the compressed air the liberty of repelling, by its spring, that which has already entered; and you may readily conceive, that by managing this pressure of the finger, I retain in the figure such a quantity of water, that the whole, together, is in equilibrium in the mass. At last, as the little hole through which the water may enter or flow out, is made one of the two legs; that is, on the side of this little plunged body: if the fluid which passes into it be pushed, or repelled with a violent velocity, the oblique impression makes the figure turn round itself; for being thus suspended in the water, it is as if it were moveable upon two pivots, or upon an axis. These figures, become sometimes more light, some-

times more heavy, than the liquid in which they are plunged; not that the volume of the correspondent water changes its density or its size, but because the plunged bodies become themselves alternately more dense and more light, in matter, without changing their volumes.

With respect to these images sinking to different depths, I am of opinion, that the hole in the image E is larger than that in D, and that the hole in D is larger than that in C; and if this be admitted, the same pressure must force more water into E than into D, and more into D than into C, which at once accounts for the difference in their descent.

Lady Caroline.—Tell me, Fanny, how a great number of animals, and, above all, quadrupeds, can have more facility in swimming than men?

Fanny.—When a quadruped swims, it can hold its head out of the water without much effort; but of man, the head is the first part which plunges; and even when he swims well enough not to go to the bottom, he is still under the necessity of making the utmost efforts to avoid having his face in the water; thus it is, that a swimmer is much more at ease upon his back than in any other situation.

Lady Caroline.—How is it that birds can

fly, notwithstanding they are heavier than an equal volume of air? Tell me, Sophia.

Sophia.—When birds fly, the chest is dilated by a greater quantity of air than enters it; they extend their wings, and their tail, increase their volume, and consequently diminish their respective gravity. The air, struck by their wings, becomes a fixed point, by which they procure motion to ascend, to descend, or to advance.

Lady Caroline.—Why does a stone bridge, loaded with men, animals, &c. which, instead of pillars, has nothing but moveable barges, still support itself?

Mary.—Because the volumes of stones and of air contained in these barges are more light, on account of the small weight of the air, than an equal volume of water.

Lady Caroline.—Why, Frederic, does a steel needle, placed gently upon the surface of a tumbler of water, swim by itself, without falling to the bottom of the glass?

Frederic.—The lightness of the air, the form of the tumbler, and the viscosity of the water, produce this effect. The air clings to the needle more easily than to the water, for it is with difficulty that the needle can be moistened; the water flows even above it, without being able to wet it. On the viscid surface of the water,

therefore, which makes the parts more difficult for separation, the weight of the needle, with the air surrounding it, produces a kind of cavity, in which the needle appears to lie beneath the surface of the water. It is in this way, that this little volume, compounded of the needle and the air, is more light than an equal volume of water, and therefore it must swim above the surface. In short, we may moisten the needle, and, the particles of air no longer adhering to it, it will instantly go to the bottom.

Lady Caroline.—You have answered, my dear son, with great good sense; and I shall now leave this subject, thanking all of you, my children, for your attention and rational answers to the questions which I have proposed to you. At the same time, I put into your hands a table of the relative weights of bodies of the same volume to each other; and beg that you will all commit it to memory, as it will clear up many things which have been already mentioned, and help you the more easily to understand those which are to follow.

TABLE

OF THE WEIGHTS OF DIFFERENT BODIES,

According to the best Calculation.

	Cubic Feet.	Ounces.		Cubic Feet.	Ounces.
Gold - - - - -	1326 - -	4	Brick - - - - -	127 - -	0
Mercury - - -	946 - -	10	Lime - - - - -	85 - -	2
Lead - - - - -	803 - -	2	Sea Water - -	70 - -	10
Silver - - - -	720 - -	12	River Water -	69 - -	12
Copper - - -	558 - -	0	Wine - - - - -	68 - -	6
Tin - - - - -	516 - -	2	Wax - - - - -	66 - -	4
White Marble	188 - -	12	Oil - - - - - -	64 - -	0
Slate - - - -	150 - -	0			

THE

FIFTH DIALOGUE.

ON PNEUMATICS.

Sir Thomas.—PNEUMATICS, my children, is that branch of natural philosophy which treats of the nature, weight, pressure, and elasticity of the air, and of the effects dependent upon these properties; as sound, wind, &c. This subject will be entertaining and instructive; you will find pleasure in every elucidation that will here take place; so be attentive, I request you, while I communicate my preliminary observations.

1st. Air is a fluid which covers the surface of the earth, and encompasses it on all sides. It is the most universal element, and the most necessary for the preservation of every thing that lives on the earth. It is the air that forms the winds, that makes the waters evaporate, that bestows vegetation upon plants, that supports the life of man, and of all animals. It is the vehicle of sounds, odours, &c.

2d. Air is a substance of which the nature is fixed, of which the integral parts are simple and homogeneous, and the principles united in such a manner as never to give way to any efforts that we might be able to make to discompose it.

3d. It is probable that air remains constantly fluid, because it is perfectly elastic; if it were only compressible, its parts brought together might perhaps touch each other near enough to form a hard body, and nothing could force them to depart from that situation; but the spring which they have naturally tends to rarefy the mass of which they are compounded, because the strongest compression will be vainly used to force it; thus these parts preserve that respective mobility in which fluidity consists.

4th. We may conceive of the integral parts of the air as of minute filaments, outlined in the form of spiral lines, or of screws, flexible

and elastic, and their assemblage nearly like a little packet of cotton, or of carded wool, which may be easily reduced into a very small volume, when pressed; but which, when compression ceases, always rises and spreads itself, regaining its first situation.

5th. Air, like all other fluids, weighs in every direction. Its specific gravity, although not always the same, is to that of water, as 1 is to 606, and thence up to 1000.

6th. The void, which is generally made in the recipient of an air pump, is not, properly speaking, a void; it is only rarefied air. But the air which re-enters into the void, out of the recipient, may, as people have computed it, run in a second of time the space of 1305 feet; while a wind, which in a second of time passes through 32 feet, is a hurricane capable of tearing up trees by the roots.

7th. We must suppose that the parts of air, intimately mixed with any other matter, do not any longer touch each other; but that they are immediately applied to the very parts of the body which contains them, as small hairs might be, or the filaments of cotton, which might envelop, for instance, minute grains of sand, or might be separately lodged in the intervals about to be filled between these same grains, and which, when joined together, form one

mass. Although a great number of filaments of cotton usually form a small flexible flake, which occupies a space considerably sensible, on account of all the vacuums which are in its volume, we yet perceive that it would occupy considerably fewer of those vacuums with its own matter, if these vacuities, filled with another substance, did not contribute to its bulk.

8th. The atmosphere is about sixty miles high, and the vapours or exhalations, being more or less abundant, make it more or less heavy. The air with which it is compounded is sometimes very unwholesome; not indeed in itself, but from the different exhalations which mix with it.

9th. The origin of sound is commonly found in the collision or shock of two bodies; the shaken parts of which produce a tremulation and sound on all sides to a certain distance, striking the fluids that surround them.

This tremulation is communicated to other bodies, which are susceptible of receiving it; that is, which meet in the sphere of its activity. Sonorous bodies, properly so called, are those of which the sounds, after the shock or friction ceases that produced them, are distinct, comparable with each other, and of some duration; for we must not give this name to those bodies, the fall or shaking of which occasions a confused and sudden noise, such as the discharge

of a cart of gravel, the noise of a water-fall, or the roaring of agitated billows. None but elastic bodies are really sonorous; and the sound they give is always in proportion to their vibrations, either in respect to their duration, or of the intenseness and force of their sound.

10th. In the rope as well as the bell, when we pull it for a sound, we may perceive two kinds of vibrations: the first *total,* because they belong entirely to the sonorous body; I mean those vibrations which proceed from the zones of an oval clock, or rather those which were circular before they were changed into ovals, by which we may see the string of a violin or a harpsichord under the figure of a parallelogram. The other vibrations, which we may call *particular,* belong to the insensible parts, and may be regarded as the elements of the first vibrations.

People formerly believed that bodies were sonorous by the *total* vibrations; but they are now undeceived, and fully convinced of their error. It is principally to three foreigners that we owe this correction. The last of the three, whose name was *De la Hire,* was the chief corrector of this false supposition: he proved by a very judicious experiment, that sound essentially consisted in the *particular* vibrations of the insensible parts. "Let a person," said he, "hold

a pair of tongs suspended upon his finger, and let him press with the other hand the two arms, and afterwards allow them to escape, they begin their vibrations, but they remain mute. Instead of reducing them into practice in this manner, the person must strike one of the arms with his finger, or with any other solid body, and though they will still make vibrations as they did in the first trial, yet the person who tries the experiment will have the pleasure of hearing the vibration accompanied by a very intelligent sound." Now, what can be more exactly in point with this position, than the tremulation of the parts of the iron which a person might feel if he gently conveyed his hand to it? It is therefore to the parts which tremulate, that sound must be attributed; and after this experience we should be persuaded, that were it possible to separate these two species of vibrations, we should never have any sound with those we call total: but when the last arise from the first, (and this is the most usual case, although they make not the sounds by themselves,) they regulate the force, the duration, and the modification of them.

11th. The air transmitting sound ought to have a certain density, that its parts may act strongly enough and freely each on the other. It should be elastic, because the movement of

the vibration originates in the spring of the parts.

12th. Sound runs through 173 fathoms, which are 1038 feet, in a second by day or by night, in serene or boisterous weather. The motion of light has therefore no connection with the propagation of sound, the mingled vapours with the particles of air do not interrupt the motion of vibration. If it blow a wind, of which the direction be perpendicular to that of sound, this has the same velocity as it has in calm weather. If the wind blow in the same line, traversed by the sound, it retards or accelerates according to its own velocity; I mean, that, with a favourable wind, sound will surpass by 173 fathoms in every second the velocity of the wind; on the contrary, if the wind be directly opposed, the velocity of the sound is still uniform; that is, in equal and continuous times, it will always traverse a like space. The intenseness or force changes nothing in the velocity of sound. Although a strong sound extends itself farther than a weaker, yet the latter, as well as the former, goes through 173 fathoms every second.

13th. We must believe that the particles of air, differing infinitely in size, differ also in their degrees of spring, or elasticity, as a blade of steel would make the springs more stiff of

both, if it were divided into unequal portions. Place a sonorous body wherever you will, it must find in the common mass particles of air, of which the spring is analogous to its own, and which will consequently be capable of receiving, of preserving, and of transmitting vibrations. Thus, two cords of different tones make themselves heard through the same mass of air, but by different parts of that mass. It is true that a sonorous body acts first on all the particles of air which immediately surround it; but it does not effectually continue its action, except on those that are adapted to move precisely like it.

I shall now give you a brief account of the air-pump, on which many of our most interesting experiments in this science must depend; and as I have drawn a figure of it in order to assist your memories, I trust you will pay due attention to my observations.

The air-pump (plate iv. fig. 1,) is an instrument desinged to exhaust the air from any vessel, as the glass receiver marked L M: and its mode of acting is so nearly like that of the common pump, that whoever understands the nature and structure of the one, may easily understand the other. To obviate the danger of mistake, however, I will briefly describe the different parts.

A, A, are two brass barrels, of considerable

thickness, within each of which, at the bottom, is fixed a valve opening upwards, and communicating with a concealed pipe that leads to K. The barrels also include moveable pistons, to the upper part of which are attached racks C C, to be moved up and down by means of a small cog wheel that is turned by the handle R.—The screw V just below the brass barrels is designed to re-admit the air into the receiver when it is in a state of exhaustion; for without a contrivance of this sort, the receiver being almost entirely exhausted of air, would be pressed down so forcibly by the weight of the atmosphere on the outside, that it would be utterly impossible to move it.

With respect to the small receiver W, and the bottle of quicksilver which it contains, I must observe, there is a communication, by means of the secret pipe, between this and the large receiver; and the whole is designed to show to what degree the air in the large receiver is exhausted.

As you may probably wish to learn the manner in which the air is taken from the interior of the glass receiver, I observe that by half a revolution of the winch R, one of the pistons would be raised, and a vacuum left in the lower part of the barrel, while a portion of the air in the receiver would rush through the pipe into

the barrel. Then if the winch were turned the other way, the other piston would be raised, and a vacuum would be left in that barrel, if another portion of air were not to rush into it from the reeeiver. You must also observe, that on the descent of the first piston, the air in the barrel would open a valve, and escape by the rack C; and by the alternate working of the pistons the air is drawn out of the receiver, till there is not a suffieient quantity left to raise the valve.

Thus, my dear children, have I endeavoured to open your understandings, that you may clearly comprehend those general principles which will enable you to satisfy the enquiries of Lady Caroline, by apposite and rational answers, in the most essential parts of the present dialogue.

Lady Caroline.—Why, in many instances, Mary, does the air communicate humidity to the bodies which it touehes?

Mary.—I imagine it communicates to them some of those aqueous partieles with which it is itself more or less impregnated.

Lady Caroline.—Your answer, my good child, convinces me that the preliminary notions whieh Sir Thomas endeavoured to inculeate, were not lost upon you. Your allusion is very just to the natural humidity of the air, which, were it not

for the sun, would actually keep us in perpetual damps. Now tell me, my dear, how the air dries linen?

Mary.—I suppose, that, eongenial to the nature of the sponge, it imbibes the watery particles contained in the linen.

Lady Caroline.—What is the reason that cordage and sails that have been steeped in sea-water, are dried in the air with so much difficulty?

Mary.—The water stubbornly adheres to the saline parts attached to the superficies, and the air from this resistance takes a long time to imbibe it.

Lady Caroline.—Whence eomes it, Henry, that a barometer which has not been filled before the fire, that is, of which the mercury has not boiled in the tube, appears without the brightness it ought to have? And whence come all those little bubbles which we perceive in many of those instruments?

Henry.—Sir Thomas has already given me to understand, that when we pour out into a vase, any liquid which forces the air to rush out, there always remains a layer of this fluid or air adhering to the sides of the vase. It is not commonly observed, because it is very minute and transparent; but it becomes perceivable by the eye, when it is dilated by the vase

being strongly heated, or when it is placed in the open air.

As for the bubbles, they are produced in the same manner; for the surface of the inside of the tube is obscured with the remaining particles of air, they being in reality nothing more than the mercury intermixed with these particles.

Lady Caroline.—A volume of air of two or three pints, taken at hazard in the atmosphere, renders an ounce of salt of tartar humid and more heavy than common tartar. What is the cause of this, George?

George.—It arises from the salt being imbibed by the aqueous particles with which the air is charged.

Lady Caroline.—When we begin to empty an air-pump, its sucker at once descends without any obstruction. How is this effected, Kitty?

Kitty.—It is effected by the dilatation of the internal air, which descends into the pump, and pushes the sucker down with a force almost equal to the resistance of the external air.

Lady Caroline.—Why does the sucker, William, resist still more in proportion as we pump the internal air from the receiver?

William.—The more internal air we pump out, the more freedom of space has that air

which remains, and is greatly dilated; but, as the more it is dilated, the less strength has it to second the hand, we feel more sensibly the resistance of the external air, and consequently the sucker appears to resist a great deal more.

Lady Caroline.—How does it happen, Elizabeth, that, leaving the sucker free on its descent, it re-ascends of its own accord?

Elizabeth.—The sucker being repelled by the external air, finds not in the rarefied air of the receiver a resistance equal to the force which repels it.

Lady Caroline.—By allowing the exterior air to enter into the receiver, by turning the key and the tube of communication, the recipient comes off. Give me, Fanny, the reason of this.

Fanny.—The return of the air pushes it back to the exact height of it, with an elastic force, equal to the action of the gravity of the external air which had pushed it down.

Lady Caroline.—By drawing up again the sucker, we see a kind of smoke, a small rain, and the sides of the receiver sullied and obscured from within. What is the cause of this effect, Edward?

Edward.—The internal air which is rarefied in an instant, pushes and shakes the imperceptible vapours which it contains, and which it

can no more support, if it be in a certain degree of rarefaction. These vapours, re-united in the concussion, and in their fall, pour down rain. The air which is dilated at the same time, and with vast rapidity, briskly darts on all sides round a great number of particles of water; which, thrown with the vapours on the sides of the recipient, sully it within, and darken it by shutting up the passages of light. This happens after it has been placed in a moistened skin, which is extended on the platen.

Lady Caroline.—The hand becomes closely attached to a small recipient open at the top, when we make a void by the air-pump: this does not take place before the void be made. How can you account for this, Sophia?

Sophia.—So long as the recipient is full of air, as dense as that of the atmosphere, the hand of a person is not only pressed upon its brim, but, also, upon the mass of the fluid which is there shut up, and resists the external pressure: but when the recipient is void, the hand, always pressed by the air without, is no more supported but by the rim of the recipient; and to separate it from it, it were necessary to make from the earth upwards an effort capable of raising the column of air which weighs upon the hand. Now, the weight of this column is equal to that of a cylinder of mercury which should

have for its base the plane terminated by the borders of the recipient, from twenty-seven to twenty-eight inches height. It follows thence, that this pressure is so much the greater, and more violent, as the recipient has more overture upwards; therefore the hand adheres to it much more than does the extremity of the finger, when a person places it upon the very hole which is in the centre of the platen; and by the same reason, a key drilled, when sucked by any person, and afterwards attached to the tongue or to the lip, cannot be detached from either but with the greater difficulty, as the channel of the key is more wide.

Lady Caroline.—This external pressure of the air, which proceeds from its weight, does not break the bells of glass with which we cover the platen of the air-pump to make the void. Can you, Frederic, assign a reason for this?

Frederic.—These vessels being always made in the form of a cylinder or of a vault, their external surface is necessarily greater than that within. All the parts which compose the thickness, resemble those with which arches are made; they are likewise similar to wedges, or to truncated pyramids which mutually support each other, in proportion as they are pressed towards an axis or common centre, by the action of a fluid which weighs in all directions.

What clearly proves that the circular form defends the glass globes against the weight of air, when they are void, is, that they infallibly fly to pieces when they have any other figure; and thus it happens to two sides of a bottle which is square, each side is pushed towards the other by two columns of air, a strength which they cannot resist, unless they be supported by an interior force, equal to that which impels them. Now they are not supported by the pumped air of the square bottle, the parts of which, not being disposed in the form of a vault, do not lean on each other, and consequently cannot give mutual assistance.

Lady Caroline.—Why do bottles of thin glass, flat on both sides, and usually covered with osier twigs, very often burst, when carried up to the mouth half full of liquor in order to drink? Tell me, Henry.

Henry.—It is because the suction rarefies the internal air, and the weight of the atmosphere, acting on the two flat sides, bears them one against the other, and cracks the glass.

Lady Caroline.—Whence proceeds the great noise that accompanies these kinds of casualties, which always, by the suddenness of their report, at the first instant, make people start? Tell me, George.

George.—This effect results from the circum-

stance of the air entering with great velocity; for we have heard before, that the air of the atmosphere re-entering into the void, flies with a velocity that will make it traverse 1305 feet in a second: the air, I say, enters with great velocity, and all at once in great volume, in a void vessel of which it strikes the sides; for the noise primitively comes from the shock of the bodies, and fluids are very capable of clashing against solids.

Lady Caroline.—Whence results the noise that we hear, when we rapidly pull off the top of a tooth-pick, or pin-case? Tell me, Kitty.

Kitty.—We then make a void which the air from without hastens to fill, as soon as the access is free to it. For during the time that we open the case, its capacity increases, and the internal air in it becomes so much the more rare as it is contained in a larger space.

Lady Caroline.—The air that we breathe in a valley is more dense than that which we inhale on a mountain. How does this happen, William?

William.—The air is compressed into itself by its own weight in the valley; and that of a mountain is charged with a column of less length than that of the valley: it must therefore be compressed a great deal less, and of course be not so dense.

Lady Caroline.—I have here a little machine, consisting of two mills *a* and *b*, (plate iv, fig. 2,) which are of equal weights, and turn equally free on their axes. The vanes of *a*, however, are placed edgeways, and those of *b* broadways, for a particular reason. By means of the spring *c* resting against the slider *d* in each mill, the vanes are kept motionless; but on my pushing down the sliders, both mills set off with equal velocity. Now, Elizabeth, tell me, what you observe?

Elizabeth.—I observed, Madam, that the mill *b* was evidently declining in swiftness, while the other seemed to run round with unabated velocity. The reason, I apprehend, is, that as the vanes of the mill *a* are placed edgeways, the resistance of the atmosphere is very trifling, and it may consequently go round much longer than the mill *b*, which seems to meet the air with its whole surface.

Lady Caroline.—I now place them under the recipient of the air-pump, and set them a-going after I have exhausted the air: You now perceive that both the mills turn round considerably longer than in the open air, and that they both stop at the same moment. Can you account for this, George?

George.—Your ladyship's experiment has clearly demonstrated the resisting power of the

air; and it also proves that its resistance is proportionate to the surface opposed to it; for the mill which met the air by its edge only, continued to move the longest while they were both exposed to it; but now that is removed, they both stop together; having nothing to check their motion but the friction on their pivots, which is exactly the same in both cases.

Lady Caroline.—Why, Henry, do we see two hemispheres, from which we have pumped the air, attach themselves strongly to each other, yet easily separated when air has been restored?

Henry.—When the internal air of the two hemispheres is rarefied by the action of the pump, the force of its spring is by that means more weakened, the equilibrium is broken, and the adherence of the two hemispheres is proportional to the difference between the density of the air that externally resists, and that of the air which resists within; so that if this one could be reduced to a cipher, it were necessary to employ, in order to separate these two pieces, an effort somewhat greater than the weight of a whole column of the atmosphere, of which the base shall have six inches diameter; this would produce 400 pounds weight, by only supposing, according to the common calculation, that a column of the atmosphere makes a pressure of ten or eleven pounds weight above a circular

space of one inch diameter. At last, when the air resumes its place in the hemispheres, they easily separate, because the effort that the internal air makes to extend itself, and to remove these two circular cavities which opposed it, is precisely equal to that of the atmosphere which externally presses them, and each of them is in equilibrium between two powers of the same value.

Lady Caroline.—Whence comes it, that when we place under the recipient the two hemispheres strongly united together, we cannot separate them, not even by the means of a bar of iron, well flattened and edged at the end, which we have passed betwixt greased skins; for, after this, one would imagine that their disunion would be easily effected, because the recipient, though nobody may have pumped the air out of it, ought to hinder above the hemispheres the action of the atmosphere. Whence, Fanny, I ask, does the cause of this proceed?

Fanny.—When we place the vacant hemispheres under a recipient, which takes from them all communication with the atmosphere, it is no more the weight of this atmosphere which restrains the two hemispheres, and keeps one against the other; but it is the re-action of the mass of air, previously compressed by this weight, which is capable of the same effects.

For this reason the two pieces cannot easily separate, till we have relaxed the spring of the surrounding air, by diminishing its density through many blows of the sucker, and thereby rendering it as much rarefied as that which remains in the two hemispheres.

Lady Caroline.—The two hemispheres placed in the recipient from which we have easily pumped the air for their separation, cleave again to each other, when we give once more to the recipient which contains them, the air which we had taken from it. Tell me the reason of this, Mary.

Mary.—The air of the hemispheres and that of the recipient being rarefied, the forces are equal; they ought then to separate very easily, when they are drawn from each other; but if the air, re-entering into the recipient, find the two hemispheres rejoined in such a manner that it cannot introduce and extend itself, as it has done in the rest of the vessel, it presses them anew, one against the other, on the same principle that they had been at first attached, and with as much force, if there be the same difference betwixt the air without and that within.

Lady Caroline.—How does it happen, Edward, that when a vacuity is made, the recipient is strongly united to the platen?

Edward.—It happens by pulling down the sucker from one end to the other of the pump; we thereby produce a space without air, in which that of the recipient fails not to extend, in virtue of its elasticity; but a mass of air which divides itself into two spaces, necessarily becomes more rarefied than either of the two; and consequently, being no longer in equilibrium with the air of the atmosphere, this last must weigh a great deal more upon the recipient, and unite it to the platen with so much the more strength, as the internal air is more rarefied.

Lady Caroline.—Why, Sophia, when a bladder is placed under the recipient, with a small portion of air in it, does it swell to such a large size?

Sophia.—It swells by the rarefying of the small portion of air contained in it, in proportion to the loss of the density of that which surrounds it.

Lady Caroline.—Why, in a similar case, does not a body of lead weighing twelve or fifteen pounds weight, hinder the bladder from swelling? Tell me, Frederic.

Frederic.—It cannot swell, because it would not be equivalent to the pressure of the air which ceases to act around in the recipient.

Lady Caroline.—A bottle of thin glass, and

full of air, corked, bursts in the void or recipient. Give me a reason for this, George.

George.—There is nothing to make an equilibrium to the spring of the air that the bottle contains, and which makes a continual effort to discharge itself.

Lady Caroline.—Can you, Kitty, account for an egg, placed in a goblet, emptying itself by a hole made with a needle in its under part, when the air is rarefied around it.

Kitty.—An egg, particularly if it be an old one, contains air which swims above in the most elevated part of the shell, on account of its lightness; this air extends itself and chases before it the contents of the egg, in proportion as we diminish the pressure of the external air, with which it was at first in equilibrium.

Lady Caroline.—How does the egg, William, fill itself again by the same little hole, when the air is allowed to re-enter the recipient?

William.—We have no sooner given air to the recipient, than its pressure makes the matter of the egg re-enter, and squeezes the internal air into the space that it first occupied.

The following explanation, Madam, I presume, you will think obvious: if in a phial full of water, of which we plunge the orifice in a vessel of any sort, a bubble of air is let in, it cannot fail to occupy the superior part; and

if you transmit the whole into the recipient, in proportion to the rarefied air within it, we must rarefy that air. We see that the bubble extends itself more and more, and precipitates the water which is shut up with it; after which, if the air re-enter the recipient, the liquor re-ascends, and the air resumes its first volume above it.

Lady Caroline.—My good boy, your explanation pleases me much. Now, Elizabeth, I have a question to put to you. The withered skin of a stale apple loses its wrinkles and becomes smooth in the recipient. Tell me the reason of this.

Elizabeth.—The air which is under the skin extends itself and raises it. It becomes more wrinkled than before when you withdraw it from the recipient, because the air contained in it, having taken a larger scope, has nevertheless only gone out in part; consequently the air in the apple being less, it has less power to repel the pressure of the external air; and for these reasons the wrinkles of the apple must be augmented.

Lady Caroline.—The air gun (plate iv. fig. 3) is in appearance very much like a common fowling piece, with the addition of a round hollow ball C, containing the condensed air, which is forced into it by a syringe, and then

screwed to the barrel of the gun. This ball has a valve opening inwards, and when the leaden bullet is rammed down, the trigger being pulled back, forces down the hook *b* upon the pin *a* connected with the valve, and liberates part of the condensed air. I now ask you, Henry, how a person can shoot many balls from this gun one after the other, and whence a sufficient force is derived?

Henry.—The condensed air makes a strong effort to get out; and as soon as it has effected this, by rushing through a hole in the lock into the barrel, it carries off every thing it meets with; the ball then receives a velocity almost equal to that with which the air flew off; but as the sucker of its pump does not remain open for an instant, there flies from it at every time as much as is necessary to send the ball to a considerable distance. If you then charge again, and put the gun on its cock, another ball darts from it.

In this gun, if it be well made, the copper ball will contain 15 or 20 separate charges; so that it is capable of doing much more execution in a given time than a common fowling-piece; and though the strength of the charges must diminish each time, the sportsman may furnish himself with a spare ball ready filled with condensed air.

Lady Caroline.—We throw into a clear fire small globules of glass, called crackers, which burst with a very loud report. What is the cause of this, Fanny?

Fanny.—A violent heat dilating the air contained in the globules, makes it act within them with such force that they fly to pieces. The proper name of this globule is what Sir Thomas calls *æolipile*, Madam, if I am not mistaken.

Lady Caroline.—You are very right, Fanny, and it pleases me to hear you express with technical propriety so common an incident. Chesnuts burst under great heat. Why so, Mary?

Mary.—The air contained under the rind being dilated by fire, acts against it to make a free vent for its liberation. The more the rind resists, the louder is the rupture, because the air has the time of being more dilated, and of course acts with greater force.

This effect does not take place when the rind has been cut previously to their being put to the fire; the reason of this is, that the dilatation of the air finds an easy issue, and consequently makes no kind of effort.

Lady Caroline.—When we heat a bottle, Edward, of which the neck and the orifice are so very narrow, that there are no means to fill it, not even by the use of a funnel, why do we very easily conquer it, after having heated the

bottle, and plunged its orifice immediately into the liquor we wish to introduce into it?

Edward.—By dilating the air by heat, we force a great part of it to issue out, and that which remains, beginning to condense in proportion as it cools, leaves a vacuity, at which the weight of the atmosphere conveys in the liquor.

Lady Caroline.—The air of a chamber is rarefied when there is a lighted stove in it. How does this happen, Sophia?

Sophia.—The air is not so much confined, but that it can communicate a little with that on the outside of the room, by small chinks or apertures which happen to be in the doors or the windows, where the air from the stove has liberty to extend itself.

We must observe, that the air of this chamber, thus rarefied, and less dense than the atmosphere, must hold in equilibrium with it; because, by heating, it acquires a degree of spring which enables it to support the pressure of the atmosphere. The same cause which diminishes its density, by so much the more increases its spring, and one is a succedaneum to the other.

Lady Caroline.—How does it happen, that when we light a fire in the chimney-place of a

room, the air is thereby rarefied without any increase of its spring? Tell me, Frederic.

Frederic.—As soon as the equilibrium ceases betwixt the two columns of the atmosphere corresponding to the openings of the two extremities of the chimney, that which weighs below having all its density, surpasses the other which is partly rarefied, and then there occurs a current of air from the lower extremity to the upper.

The smoke, instead of spreading itself in the chamber, takes its vent up the chimney, because the air of it, being rarefied by heat, resists less the smoke than the air of the chamber, and the smoke impelled forward by the fire must of necessity describe a right line, or any other passage open for its ascent.

Lady Caroline.—In the operation of cupping, we apply upon the skin a small vessel of glass, which acts as a recipient, and which at its cope has an aperture to which we adapt a small pump: when a vacuity is made through this pump, the skin swells under the recipient or glass. Give me the reason, George, if you can.

George.—The air contained under the skin, finding no longer the resistance of the atmosphere, raises by dilatation the skin produced by the effects of the operation; and when it is

sufficiently pulled up, the recipient is taken off, and the part thus puffed up is scarified with small lancets made for this purpose.

Lady Caroline.—Why, Kitty, does a bird placed in a recipient, of which the air is considerably rarefied, cease breathing?

Kitty.—The air no longer participating with the weight of the atmosphere from which it is separated, its spring, as well as its density, being very much diminished, it is impossible for the lungs of any animal to dilate, because the fluid which is accustomed to be there inhaled, ceases to exist; thus the alternate motion which we call respiration, cannot any more have place, since of the two powers which produce it, we suppress one and weaken the other, by the absence of the indispensable weight and spring of the air.

Another cause gives death to the confined animal; which is, that the air contained in the different capacities, and even in the fluids of its body, strongly rarefies when it is no longer supported by the pressure of the external air. All these portions of dilated air, acquiring a volume much greater than that which they had in their natural state, compress, and often break the parts where they are engaged; or, rather, where they make obstructions in the vessels, and arrest the course of the humours.

Lady Caroline.—Whence comes the air which we see issue from a fish when put into a vessel of water and covered with the recipient? Tell me, William.

William.—This air was in the body of the animal, but it flows out in the shape of bubbles, which appear upon the surface of the water proportionably to the void in the recipient, because it finds less resistance on the part of the rarefied air which surrounds the fish.

Lady Caroline.—Why, Kitty, does not the privation of air give death so soon to aquatic and amphibious animals, as to others?

Kitty.—There is every appearance that the first have a different way of respiring from the others. An air more rarefied may therefore be sufficient for them. However, there is that which most accelerates their death in the void; it is the internal air which dilates and puts the whole system of the animal into a state of agitation and destruction.

Lady Caroline.—Why, Elizabeth, does a carp swim only on the surface of the water, notwithstanding its inclination to the contrary when it is placed in a vessel under the recipient?

Elizabeth.—Because the double bladder which we find in this fish, as well as in many others, is distended on this occasion, and blows up the

body of it, which now becomes lighter than the volume of water to which it corresponds, and consequently it must swim on the surface of the water.

The same fish becomes less, and is involuntarily precipitated down, when the air is allowed to re-enter the recipient, because the little bladder, by dilatation, is partly voided, and the remainder of the air which it contains, when it resumes a density equal to that of the atmosphere, is no more capable of filling it, as it may be proved by opening the body of the fish.

Lady Caroline.—How, Henry, do almost all insects, even those which live in the open air, such as butterflies, common flies, &c. suffer, without perishing, the privation of air, sometimes for fourteen or fifteen days?

Henry.—As they have in their bodies but very small volumes of air, the dilatation is extremely minute. The void cannot be mortal to them, but through the want of respiration. These little animals may probably be a long time without respiring even the grosser air. However, Madam, I dare say, that you will agree to this, that the natural state of all these animals is to breathe.

Lady Caroline.—It is evident, that they breathe, though the air may never be too rare-

fied for them; and as they can support the recipient so long as fourteen or fifteen days, you may be assured that it is the want of food which causes their death, and not the want of air, which I might have previously explained to you. However, my dear Fanny, can you explain to me the cause of fish dying under the ice?

Fanny.—They die through the want of air; since we may avoid this accident by taking care to break the ice.

Lady Caroline.—Why might we not save the lives of many persons who have not been too long in the water, if instead of holding them suspended, the head downwards, and often in a cold chill air (which is the custom in many places, and actually effects their death), we endeavoured to re-animate the blood by a gentle heat, by spirituous liquors, by friction, and by holding them in a natural and commodious situation? Can you explain this, Edward?

Edward.—Although their stomachs may be overcharged with water, this is in reality the slightest consideration: the first object should be to assist and restore suspended animation.

Lady Caroline.—If any animal be suffered to remain in a fluid a few degrees more dense than the common air, it will die in the space of five

or six hours. What is the cause of this, Sophia?

Sophia.—Violence is done to it by breaking the equilibrium betwixt the internal air of their bodies, and that which surrounds them.

Nor would animals scarcely exist any longer, were they pent up in a foul and unwholesome inclosure, pressed one against the other, and never renewing the air they inhale: for the air loses its spring by remaining too long on the lungs, or in the sanguine vessels; and, its elasticity being destroyed, it is no longer capable of giving respiration.

Lady Caroline.—A lighted flambeau, exposed against the ground in the celebrated Grotto del Cani, in Italy, is extinguished in a second of time. Can you form any idea of the reason, Frederic?

Frederic.—I should imagine that it is owing to sulphureous exhalations, which, I have heard your Ladyship say, ascend in great quantities from the bottom of this grotto. I likewise remember your Ladyship telling us, that if a dog were thrown into it, he would immediately die; which I attribute to the same cause, the sulphur overpowering and suffocating the animal.

Lady Caroline.—Why does a candle go out when it is shut up in a vault full of wine in fermentation? Tell me, George.

George.—Because the volatile spirit contained in the wine dissipates and fills the vault with exhalations, which extinguish the light of the candle.

Thus also the exhalations of burning copper, shut up in a glass, will suffocate, in a very short time, any animal that may be held over it.

Hence those who work in mines, either of coals or of metal, die on the spot, when certain exhalations suddenly arise from the bottom of the quarry.

Again: a man who should place his nose to the bung-hole of a tun of wine in fermentation, and should breathe but once over the exhalations, would be struck dead immediately, as if with a thunder-bolt.

Master brewers have also frequently found their draymen dead in their brewhouses full of fermenting porter, the consequence of having imprudently shut all the windows during winter, for preserving themselves from the cold: it is therefore absolutely necessary, for avoiding such fatal accidents, to open every passage of the brewhouse in winter as well as summer.

Lady Caroline.—Why is it unwholesome to remain a long time in a bed of which the cur-

tains are extremely thick, and closely shut? Tell me, Kitty.

Kitty.—Because the small mass of air contained within, not being renewed as it ought continually to be, its purity cannot fail of being adulterated by the insensible transpiration and respiration of the body.

Lady Caroline.—To what cause must we attribute epidemic maladies, or contagious diseases, which spare not the noble any more than the peasant? Tell me, William.

William.—They are to be attributed to an infected air, the effects of which are experienced by communication, or by the winds and other changes in the atmosphere.

Lady Caroline.—In warm weather we have recourse to fresh drinks, to bathings, to cold liquors, to ice, &c. What is the reason of all this, Elizabeth?

Elizabeth.—It is that the air, which by this means we contract, may, after enlarging itself, re-establish the vigour, by removing the oppressive languor of the body which the heat had caused, and thus, by continued incitements to digestion and nutrition, that heat is at length conquered.

Lady Caroline.—Why do the most combustible matters refuse taking fire in an air that is not free? and why, when they are set on fire,

are they suddenly extinguished in the recipient, Henry?

Henry.—As the flame consists in a motion of vibration, impressed on the parts of combustible bodies, which are dissipated under the form of an extremely subtile fluid, this motion cannot have place but in a spring medium, capable of re-action, which restrains the flame of it. Now this spring fails both in the recipient and in an air that is not free. It thence follows, that a candle is by degrees extinguished under the recipient, in proportion as the air is rarefied. Gunpowder thrown upon a burning hot metal, previously placed in the recipient, where the vacuity is afterwards made, produces nothing but smoke, or at the most a very feeble flame, which in an instant goes out: this arises from the spring of the air diminishing in proportion as the fluid is rarefied; for the vibrations of the flame experience no more the re-action of the fixed part.

If, however, we employ, by degrees, a certain quantity of powder, that which should fall the last into the recipient would infallibly be inflamed, and might blow up, with very great danger to the manager of the machine; because the sulphur and the salt-petre burning, produce air in the recipient, and this air increases the spring of that which is in the vase. Thus, you

have nothing more to do, but to throw some grains of powder upon the burning metal, to make a small quantity of air issue from these grains; which, however, is incapable of considerably increasing the spring of that which was rarefied in the recipient.

Lady Caroline.—Why is a red hot coal extinguished when we put it into inflammable liquids, such as spirits of wine, oil, &c.? Tell me, Fanny.

Fanny.—These liquids are so very compressible, that we must consider them as destitute of the necessary degree of elasticity; for the flame cannot rise nor be kept up, but in a spring medium.

A red hot coal, however, communicates in a moment fire to spirits of wine and to oils, when these substances are, by burning, reduced into vapours. In the state of vapour these bodies are mixed with air, and form with it an elastic fluid, of course, capable of a re-action, such as is necessary to support the inflammability.

Lady Caroline.—Why, Mary, does the fire burn a great deal better, and fuel more quickly consume, during frosts, than at any other time?

Mary.—It is because the air is more dense, and there is a greater spring in frosty weather. A chafing-dish full of lighted charcoal extinguishes very soon if it be exposed to the heat

of the sun, particularly during the summer, when the air has the least spring, being the most rarefied, or extended, and occupying more space.

Lady Caroline.—Why, George, do conflagrations usually cease, when they penetrate into places where every aperture may be closed up, provided their walls are likewise able to withstand the efforts of the air, and the vapours which dilate within?

George.—It is not enough that there be air around the inflamed materials to keep up the fire, it is necessary that this air be free, and that it have a certain purity. Now, when a place is well stopped up, the air has lost its freedom, and heterogeneous particles, issuing from the inflamed bodies, corrupt and deaden it.

Lady Caroline.—How does the breath of the mouth, or wind, put out a wax-candle, Mary?

Mary.—It dissipates the parts of the flame, and separates the fire from its aliment; for every time that this dissipation does not take place, the fire, far from ceasing, increases.

Lady Caroline.—When we attempt to raise fires in the void, and particularly those which originate in fermentation, why does the recipient fly into pieces, to the great danger of the spectators?

Edward.—The liquors adapted for raising

fires in the void, being so much the more active, as they are less constrained by the weight of the atmosphere, their explosion must naturally be more violent in the void than any where else, whether they produce by fermentation a great quantity of air, of which the spring is instantaneously displayed, or whether (and this is the best reason), being reduced into vapours, they dilate themselves by their own conflagration.

Lady Caroline.—Here is a glass of clear water, in which I put a piece of wood or stone, a nut, an egg, or other solid porous body, in such a manner that they may be entirely covered with the water. To effect this, I make use of a small piece of lead tied to the substances which do not sink, in this instance the *nut* and the *piece of wood.* I now take the glass and place it upon the platen of the machine with the recipient over it; then make the pump act to rarefy the air. At every blow of the sucker you observe that there issue out innumerable bubbles of air from the bodies at the bottom of the glass. I will now take out one of the bodies, the nut, for instance, which you may see is penetrated by, and filled with the water, more than it could possibly have been by a simple immersion. Can you account for this, Sophia?

Sophia.—The air which is inclosed in the pores of the wood, stone, and other bodies, which your Ladyship put into the glass of water, is, at least, as dense as that of the atmosphere, of which it supports the weight. When you suppress that resistance, or diminish it by the action of the pump, this air is dilated by virtue of its spring; its volume increases, and, unable to remain any longer in the small spaces which contained it, it flies into the water, and becomes visible under the form of little globules, which rapidly rise on account of their respective lightness.

The air which passes from the solid body into the water which surrounds it, is formed into little balls, and this happens, generally speaking, to every fluid which is plunged into another fluid with which it cannot mix but with great difficulty; and for this reason, that all its parts, equally pressed on every side, tend to one common center.

When you permit the air to re-enter the recipient, the water in the glass is more compressed than it was when in the rarefied air; it consequently supports itself upon all the surfaces of the bodies which your Ladyship put into the water. The air which has been rarefied in the pores of the nut, obeys this new pressure, contracts itself into a smaller space,

and the water tends to fill the voids which the air has left. This is the reason, that when these bodies are opened after the experiment, we see the objects penetrated by and filled with water.

Lady Caroline.—Why do these drops of water and of mercury, which you see I have placed in the recipient, still keep their natural globular form, Frederic?

Frederic.—Their parts tend to a common center, being equally pressed on every side, just as they are in the recipient; for we cannot imagine that it is a real void, but merely a rarefied air. There is always in the recipient a fluid independent of that which issues by means of the pump.

Lady Caroline.—In proportion as I rarefy the air of the recipient in which I have, as you see, placed a wine glass exactly two thirds full of champaign, the air which it contains disengages itself and rises to the surface, on which you may observe, it causes a foaming. You now see it spouting forth to a considerable distance sparkling globules which increase in number and in size, flying more and more distant. Give me the reason of this, George.

George.—As you suppress by rarefaction the external air, you give room to that in the champaign to disengage itself; for, being no

longer loaded as it was before, it acquires a greater volume; and its respective lightness, now more powerful than the friction, and the other causes which tended to restrain it, fails not to elevate the liquor to the surface.

Lady Caroline.—I now put into the recipient spirits of wine, and luke-warm water, in these two glasses separately. I then draw out the air to a certain degree, and you see they all on a sudden gush over their surfaces in copious ebullitions. How is this brought about, Kitty?

Kitty.—The more easily a liquid separates, the more quick and more large are the bubbles of air that ascend from it; for it finds a less resistance to conquer in the enlarging itself to a greater expansion. Now, spirits of wine and luke-warm water, I have heard your Ladyship say, are very fluid, and easy to be separated.

Lady Caroline.—I now put into the recipient, beer in one glass, and milk in another. You perceive that they rise up into a high froth; so much so, that the glasses are become wholly empty. Explain the cause of this, William.

William.—The beer and the milk, being of a viscous nature, are divided with difficulty: the globules of air which are formed in it, remain enveloped in minute bladders, and rise very slowly; and as they are constituted of particles of the liquors which are difficult to separate,

the bubbles of air, by carrying them off, empty the glasses.

In these experiments, Madam, we observe that the bubbles of air increase in volume as they approach the surface of the liquors. As they ascend, they have a less weight to support, and, of course, their dilatation is increased.

Lady Caroline.—Butter, resin, melted gum, and other liquids of a similar nature, swell by degrees, and surprise us at first with their sudden effervescence; they are frequently also very dangerous in boiling. Can you account for this, Elizabeth?

Elizabeth.—The grosser parts of the air are mixed with these coarse liquids, and when put on the fire, being already inflammable in their own natures, the persons who are in the room, are in imminent danger.

Lady Caroline.—The air that is extracted from leavened paste, from fruits, and from the greater number of vegetables, suffocates animals, extinguishes fire, and strikes our sense of smelling with a very annoying and piercing odour. To what, Henry, do you attribute this?

Henry.—This air is not only impure, but actually poisonous. It is a compound fluid, partaking very much of the nature of whatever it flows from, and is loaded with a copious vapour,

which makes up the greatest part of its volume.

Lady Caroline.—How do persons, who drink in too great quantity of spirituous and fermented liquors, destroy their lungs and coagulate their blood? Tell me, Fanny.

Fanny.—All such liquors, in general, as well as crude aliments, contain and convey with them a great quantity of tainted air, which is afterwards dilated with alarming efforts in the stomach.

A moderate use of aliments, as well in beverage as in food, is what every person should observe for the preservation of their health.

Lady Caroline.—We call a certain appearance of the air and sky, a serene heaven. How is that appearance caused, Edward?

Edward.—During the day, the rays of the sun heat at the same time both the earth and the air which environs it. When the sun is set, the heat that it had communicated, abates imperceptibly; but it preserves itself a longer time in bodies which possess more matter, so that during the night, the earth and the waters are commonly more warm than the air of the atmosphere. Then the matter of fire, which tends to expansion, always uniform with the nature of the fluids, passes from the earth into the air, and carries with it the more subtile parts of

terrestrial bodies, which it detaches and animates by its motion. On this account, that part of the atmosphere which is nearest to the earth receives a greater quantity of these evaporated substances. Hence that moisture which we often feel upon our clothes when we walk out in the evenings of spring and autumn; and this we call a serene heaven.

Lady Caroline.—Whence proceeds the dew? This is an interesting subject, and I wish you would explain it at large, Frederic.

Frederic.—The serenity just spoken of lasts all the night in the seasons, and in the climates where the earth receives a genial heat during the day. At the rising of the sun, the heat begins to warm the atmosphere, and the air beginning to dilate, drops its vapours, too subtile to fill its pores, or rather, they follow the matter of fire, to which they are still united, and return them towards the earth. Such vapours, and so falling, are called dew.

Lady Caroline.—Whence comes the hoar-frost; can you tell me, Mary?

Mary.—The small drops which make the dew, are frozen into a feathery kind of ice by a cold air. It is this kind of frost that melts and dissipates as soon as the sun begins to make its heat felt.

Lady Caroline.—What are mists, Kitty?

Kitty.—They are large, thick, expanded heaps of vapours, and gross exhalations, which their own gravity or violent cold condenses, and hinders from rising any higher than a small matter above the surface of the earth, which is moistened with unwholesome damps. The severe cold, which unites the gross vapours and sickly exhalations, makes the gross mists very malignant.

Lady Caroline.—Why, George, in frosty weather, are the windows of our chambers frozen within, and not without?

George.—The air is warmer within our chambers than it is without, so that the fire which passes through the humid vapours, runs out, always tending to spread itself in an uniform manner. It therefore carries off the vapours, but leaves them on the inside of the panes, to which they adhere, and, in spite of the warmth of the chamber, are frozen on every pane, sometimes so thick that we cannot see through them.

Lady Caroline.—Of what are the clouds composed, Kitty?

Kitty.—Of certain mists or vapours, which, when risen to a proper height, become great masses, and are floated by the wind through the atmosphere. Such are the clouds which we see suspended on all sides, and above our heads,

and which occasionally hide from us, in their course, those beautiful objects, the sun, moon, and stars.

Lady Caroline.—How is rain formed, William?

William.—The clouds often become very thick, either by the action of the winds, which push them one against another, or by the condensation of the air on which they are borne. Their parts, re-united into large drops, become too heavy, and make, while they are falling, what we call rain.

Lady Caroline.—Whence comes rime, Elizabeth?

Elizabeth.—From a mist, which cold weather freezes and attaches to the branches of trees, to dry plants, to the hair of travellers, and, generally, to every thing exposed to it. The rime owes likewise its origin to the dew, which transpires from the vessels of plants during the night.

Rime also announces thaws; because when the rime appears, it is a sign that the air is full of humid and warm vapours.

Lady Caroline.—How, Kitty, does rain purify the air?

Kitty.—It precipitates all the exhalations which are gathered together in the atmosphere during the hot weather, of which a too great

quantity would corrupt the air, and occasion epidemic maladies. We sensibly feel the good effects of rain, not only by breathing more freely and sweetly, but by the pure and transparent appearance of the air: objects are seen more distinctly and observed at a greater distance; for there never was a telescope that could shew a body so clearly as a serene heaven after a heavy rain.

Rain refreshes the air, because the region of the clouds whence it flows is almost always more cold than that part of the atmosphere in which we are. This is a fact well known to those who have seen high mountains covered with snow, when at the same time in the valleys beneath, the air has been very hot. Thus, when it rains in summer, the rain being cold water filtered through a heated air, this air must necessarily lose a great part of its heat.

Lady Caroline.—Whence results the surprising phenomenon called the water-spout, which is very often seen at sea, rapidly flowing down from the atmosphere, and sometimes on land: It is a thick black cloud which prolongs itself from the atmosphere to the ocean, in form of a cylindrical column, or rather, an inverted cone; it throws about itself a vast quantity of hail-stones and rain, and makes a noise similar to that of the sea in a violent storm; it tears up trees and houses

wherever it passes, and when it falls upon a vessel, that vessel is immediately sunk by it? Seafaring men, who well know this dangerous appearance, sail as fast as they can from it, and when they cannot avoid approaching it, they endeavour to break it by cannon balls, and if they succeed in breaking it, the danger is avoided. I ask the cause of this phenomenon, Frederic.

Frederic.—Although few observers have had the opportunity of nearly examining it, I think that the cloud, determined to turn on the double impulse of two contrary winds, of which the directions are parallel, takes the form of a watery whirlwind, which lengthens and enlarges itself more or less according to the velocity with which it turns, and follows the extent of the wind which agitates it.

Lady Caroline.—Now, Edward, tell me the origin of hailstones.

Edward.—Vapours condensed by cold weather, which freezes the aqueous particles, and they form themselves into drops, sometimes equal in size to a walnut, because many drops of rain are united together while falling; or rather when they have received a sufficient degree of cold, they freeze all the particles of water that they touch in their fall, and become like the stones of fruits, with many layers of ice. It is for this reason that large hailstones are al-

ways angular, and that those which are round, never are of an uniform density from the surface to the centre.

Hailstones which fall during a violent wind are generally of a less regular figure than the former, because the wind makes the drops of rain lose their roundness, and flattens them by compression, in a manner which preserves that form when they are frozen.

It never hails in those valleys which have their respective mountains to the east; the reason of which is, that the great quantity of rays which those mountains reflect melt the hailstones the moment they fall.

Previous to a fall of hail we sometimes hear in the air a great and crackling noise. This noise is caused by the stones which are pushed against each other by the wind; for as these little pieces of ice are hard bodies, they give a sound similar in their degree to all other hard bodies when impelled by each other.

Lady Caroline.—What is the cause, and what are the usual effects of snow, George?

George.—The cold, in the region of the clouds, condenses the vapours, and freezes the aqueous particles, prior to their union into large drops. These infinitely thin flakes of ice consist of the most minute particles of frozen vapours.

Snow contributes to the richness and fertility

of the soil; as it confines the exhalations, and is aeeompanied with particles of nitreous spirits, the warm exhalations of which, joined to it, nourish and promote vegetation.

Lady Caroline.—Why, Kitty, does mereury ascend in the barometer?

Kitty.—Because it is impelled by a heavy column of air, which is extended to the very top of the atmosphere. Thus, the heavier the air is, the higher the mereury ascends; the less the air weighs, the lower the mercury descends.

Lady Caroline.—Why, William, do the vapours weigh less when they ascend, than when they are motionless?

William.—When a body of any eonsiderable weight ascends, it cannot press downwards with the same force as it does when suspended in the air without any motion. The vapours which ascend raise and eause the air, against which they are driven, in a certain degree to ascend likewise; and as they are impelled to traverse by rising, this air then presses less downwards than before.

Lady Caroline.—If I pour on the lower mercury of a barometer fourteen inches of water, why, Elizabeth, does the mercury ascend an inch in the tube?

Elizabeth.—Beeause an inch of mereury equilibrates fourteen inches of water.

If we put into this water the orifice of a sy-

ringe, and draw the sucker, the water follows it; because by lifting it up, every obstacle to the elevation of the water, pressed by the external air, is taken away, which weighs about twenty-eight inches of mercury.

Lady Caroline.—Why, Henry, do two pieces of polished marble, when rubbed against each other, adhere closely?

Henry.—The internal air is driven out from betwixt them by friction; and the equilibrium betwixt this last air and the external air becoming stronger, acts in every direction, and weighing upon the two pieces of marble, attracts them together.

In the recipient, they would easily separate, because the pressure of the external air, diminishing in the proportion of the rarefaction, weighs no longer so much on these two bodies; less strength is therefore required to separate them.

Lady Caroline.—We are convinced, Fanny, by a great number of experiments, that the air above each part of a body presses it as much as if it supported twenty-seven inches of quicksilver, as you may observe upon the barometer at the twenty-seventh inch, or 14 times as many inches of water.

Supposing the body of a man to be six feet high and one foot broad, the air will press as much on each foot as if there were thirty cubic feet of water; each of which weighs at least

sixty-three pounds. This number taken thirty times, makes one thousand eight hundred and eighty pounds, which press upon every foot of our bodies, and consequently all the width of the body supports six times this weight, that is, 11,348 in the fore part of our bodies, and as many behind, which, together, make 22,696 pounds weight. How can so prodigious a force be supported by a human being without crushing him to atoms?

Fanny.—This weight of air equally presses our bodies on all sides, as well within as without; it therefore changes nothing in the disposition of its organs. We know that the internal air of our bodies has the same force and the same spring as that which surrounds us. The forces being equal then, there must be an equilibrium, and consequently the body will not be overpowered.

Lady Caroline.—Having proceeded thus far, my dear children, I will now propose a few questions relating to sound, wind, &c. which I hope you will find equally pleasant and instructive.

Tell me, therefore, Edward, why the bells of clocks are made of a metal compounded of tin and red copper?

Edward.—Because every compound metal is more hard, more stiff, and consequently more elastic, than the simple metals which en-

ter into the mixture; and as sonorous bodies are so much the more so, as their parts have greater spring, clock-bells are made of a compound metal, to draw more sound from them. The greatest number of small bells, however, are only of copper; but it is a bad copper, adulterated, and easily broken, called *brittle glass.* As this substance is very stiff and brittle, it is more sonorous than new copper would be, and more sweet and soft, and is properly called *molten copper.* Silver hand-bells would have but very indifferent sounds without alloy.

Lady Caroline.—On touching a bell with one's hand, or any other substance, its sound immediately ceases. Why so, Mary?

Mary.—The sound is formed by the vibrations of the particles of the bell, which vibrations are interrupted by the application of the hand or other substance.

Lady Caroline.—The bells of clocks, when they are covered with snow, produce only a dead kind of sound, similar to that of muffled drums at some funeral ceremonies. Account for this, Sophia.

Sophia.—The snow, in the same manner as the covering laid over the drum, interrupts the vibrations of the sonorous body.

Lady Caroline.—Why does not a cracked bell still preserve its vibrations and usual clear sound? Tell me, Frederic.

Frederic.—Because the limits of the cracked part reciprocally clash, and do to each other what a strange body would do in touching it, were it still unbroken. The sound would be probably less interrupted, if, instead of having a small fracture, it had been much larger.

Lady Caroline.—Why, George, do clock-makers take great care that the clappers of clock-bells be suddenly made to rise again upon the blow being given by the spring?

George.—Because they excite the sound, and that they may not alter it by remaining too long applied to the sonorous body; clock-makers are obliged to be particularly attentive to this part of their branch.

Lady Caroline.—Whence, Kitty, proceeds the sound that appears still continued to us, although it be not so, since it is only a series of vibrations?

Kitty.—Because the cessation from one vibration to another is too short to be perceived.

Lady Caroline.—Why, William, do the buzzing of flies, and the chirping of grasshoppers, and of crickets, continue so long?

William.—These sounds come not from their mouths. In the fly, it is a kind of beating of the wings. In the grasshopper and cricket, it is the beating of a species of drum, which they have in the belly, and sometimes upon the back, as may be observed on certain grass-

hoppers which conceal themselves in the bushes, and which have no wings.

Lady Caroline.—Whence, Frederic, proceeds the sound of the thong of a whip, which a carman or postillion suddenly smacks; the humming of a thin piece of notched lath, which boys call the bull-roar, and which is turned rapidly round with a piece of string; and the whistling of a switch, when we shake it with great velocity?

Frederic.—In all these cases, as well as in many others, the fluidity of the air resounds, the parts of which flow into vibrations from having been shocked by a solid body.

Lady Caroline.—Whence comes the sound of a flute or a whistle? Tell me, Henry.

Henry.—From a certain volume of air, blown from the mouth of the player, which strikes another mass of air contained in the instrument; for the vibrations of wood are of no other effect than to transmit with more power the sound already formed.

Lady Caroline.—How, Fanny, does it happen, that some people can break a wine glass with the sound of their voice, by placing it before their mouth?

Fanny.—Because they take the unison of the glass, and force, by the strength of their voice, the magnitude of the total vibrations, and con-

sequently the particular vibrations from which these last flow. Now these latter vibrations cannot be formed without the glass being shivered to pieces; of course, when they become too great, the dissipation of their own continuity produces the above effect. In short, the force of the voice operates upon the glass in the same manner as the bow of a violin, which is too forcibly drawn over the treble.

Lady Caroline.—Why, William, when a drum is beaten by the side of a calm body of water, do we perceive the vibrations upon its surface?

William.—Because the trepidation of the air communicates to the particles of water.

Thus, when we twang the cords of musical instruments near the rays of the sun, which discover the atoms that play in the air, we see in these corpuscula, vibrations conformable to those of the twanged cords, because the vibrations of the air communicate to these small bodies.

In the instance of strong sounds, such as those of church bells, the drum, and bass viol, it often happens that the panes of windows, and even wainscot partitions, trepidate. We ourselves, likewise, feel emotions of a trilling nature within us. It is very easy to comprehend, that the air, having received the vibrations of

these different instruments, not only communicates to panes and partitions, but even makes our insides shudder.

Lady Caroline.—Why does the bell of a clock produce no sound when suspended in the vacuity of the recipient? Can you tell me, Elizabeth?

Elizabeth.—Because a bell which makes its vibrations there, can communicate them to nothing; since, therefore, they only act when they transmit themselves, they must of necessity remain in profound silence; though, in reality, as Sir Thomas has observed to us, there is no absolute void in the recipient; yet the air that remains there is so very rarefied, that its too-relaxed parts have not sufficient re-action. This subtile fluid is too defective in density to place the parts in a situation to act strongly against each other.

Lady Caroline.—Why, Henry, does a bell, when placed alone on the platen, or in the recipient, sound?

Henry.—Because the sound is transmitted by the solid bodies communicating on one part with the bell, and on the other with the external air.

Were the bell in a state of suspension, it would not, as my sister Elizabeth has observed in the foregoing answer, produce any sound.

Lady Caroline.—I take this repeater, and fix it to the leaden platen, which is, as you may see, about five-twelfths of an inch thick; I now cover it with this small recipient, the rim of which I closely stop round with melted wax. I now suspend the whole by four united strings from the top of the recipient, in order to plunge it into this large cylindrieal vessel, which eontains about thirty pints of water, and entirely free from air.

We now hear the repeater strike, although it be surrounded with many inches of water; but this sound, as you all evidently hear, is very much weakened. Can you, Fanny, give the reason of this?

Fanny.—Because the sound is communieated from the repeater to the air that surrounds it; from the air to the recipient, from this to the water, from the water to the external air, and then to us. We may easily imagine that the sound, passing through so many bodies of different densities, must at last become exceedingly enfeebled.

Lady Caroline.—Whence, how, and where proceeds that rebounding of the voice, &c. commonly called echo? Tell me, Sophia.

Sophia.—From a slow and reflected sound which eomes with the same modifieation as the direct sound, and strikes the organ of hearing,

whence the direct sound makes no more impression.

These reflections of sound are never heard in open fields, but frequently in groves and woods, among rocks, and on the sides of high, irregular, and craggy mountains; because in these last places, the sound very often meets with obstacles which reflect it; this does not happen in free, open, and unconfined situations.

Echo repeats more of these reverberations by night than by day; because in the silence of the night, the tranquil air, either less agitated, or less charged with vapours and exhalations, than by day, more easily conveys to, and receive its impressions from, a greater distance.

A solid surface is fit for echo; because it reflects the sound with the same circumstances as the direct sound.

A concave surface is also adapted to echo; because it hinders the dissipation of sounds, and confines it to a certain spot.

There is no echo when the surface which should reverberate, is too near us; because it reflects the sound before the impression of the direct sound be passed; then two sounds make only one, which is that we first heard.

There is no echo when the surface which ought to reflect is too low; because the air,

which has received the vibrations of the sound passing above the surface, is not reflected toward us.

Sir Thomas.—I wish you to observe, my children, that for an echo to be heard, the ear must be in the 14th *line of reflexion*, which this little drawing may enable you fully to comprehend. If the bell *a*, (plate iv, fig. 4,) be struck by the clapper, and the undulations of the air strike the wall *c*, *d*, in a perpendicular direction, they will be *reflected* back in the same line; and if Sophia stood between *a* and *c*, as at the point *x*, she would hear the sound of the bell, by means of the undulations as they went towards the wall; and she would also hear it a second time, as the undulations returned, which would be the echo of the first sound.

If the undulations strike obliquely against the wall, they must fly off obliquely on the other side, in a line of reflexion, as *c*, *m*. Now if there be a hill, or any other obstacle between the bell and the place *m*, where a person might happen to be standing, he will not hear the direct sound of the bell, but only the echo of it, which will come to his ear along the line *c*, *m*.

In places where there are a number of walls, rocks, &c. which reflect the sound from one to the other, and where a person stands in such a situation as to intercept all the lines of reflection,

the repetition of a sound is heard several times. Thus at Brussels, there is an echo that answers 15 times; at Romeath, near Glasgow, an echo repeats a tune played with a trumpet three times distinctly; and at a place, near Milan, in Italy, the sound of a pistol is reverberated 56 times.

Lady Caroline.—Why, Sophia, since we have two ears, do we hear only the same sound at once; and having two eyes, perceive only one object at the same time, and have not a double sight?

Sophia.—In the first instance, because the sound attacks parts perfectly similar, which possess one point of common re-union in the brain. There is then but one impression in it, which must be very strong, since it is formed by the two auditory nerves being united. Thus, by having two ears, we hear better than if we had but one of these organs.

Exactly the same reason may be given for our seeing with two eyes but one appearance of any object.

Lady Caroline.—My dear Sophia, can you tell me why, among the many different tones, there are some which are better understood than others, by certain persons who are very hard of hearing?

Sophia.—The efficacy of some sounds compared with others, may be attributed to some

defect of the spiral wave, which is affected but in part. If for example, the two extremities of this part were become less sensible, by some accident, than the middle of it, the person who had this defect would hear with ease only sounds of a mean proportion betwixt the high and low. In a numerous company he would assuredly find some one, whose tone of voice would happen to agree exactly to this sound part, and who would make himself be perfectly heard by him, without speaking any louder than common.

Sir Thomas.—We will now, my dear children, proceed to the explanation of the phenomena of the winds, with their general causes: on which subject Lady Caroline will entertain us, by her usual pleasant and easy enquiries.

Lady Caroline.—What is the wind, George?

George.—The wind is a violent agitation in the air; and though there be as many different winds as there are different points in the horizon, we yet distinguish four principal ones. These blow from the four cardinal points of the sphere, and are, the wind of the north, that of the south, that of the east, and that of the west. To these four winds we add twenty-eight others, thus dividing the horizon into thirty-two principal parts, which make up the common divisions of the compass.

Lady Caroline.—Whence come the winds in general? Can you tell me, Edward?

Edward.—From a defect of equilibrium in the air; because every time that certain portions of the atmosphere become more charged, more dense, more elevated, or more pressed than others, being more heavy, they must fly off, rush forwards through those spaces where there is the least resistance, and push before them the other parts more weak; nearly like the water of a channel, raised by the throwing of a large stone into it, which moves the water in undulations, that is, wave over wave, similar to the resistance of the winds.

Lady Caroline.—Why do certain winds blow by shakes and sudden gusts? Tell me, Henry.

Henry.—These winds are produced by exhalations congregated and fermented together in the middle region of the air; which fermentations are sudden and intermittent explosions, that consequently push the air by sudden attacks.

Lady Caroline.—Why does a very impetuous wind rise sometimes all on a sudden, when a cloud is ready to burst, during calm weather? Tell me, Fanny.

Fanny.—The cloud presses the air betwixt itself and the earth, and is forced to rush rapidly down. These violent winds are usually

followed by rain; because the clouds falling produce it, and form it into drops during its fall.

Lady Caroline.—Whence, Mary, comes the spring zephyr?

Mary.—It probably originates in the great quantity of air which, from the atmosphere, passes into different mixed bodies that nature produces where less space is occupied. There is, therefore, in the atmosphere, a small defect of equilibrium, produced by a gentle wind, called zephyr.

The zephyr of autumn probably comes from the air, which at this time issues from bodies that are discomposed. It is very certain that all bodies contain air, which, by being discomposed in the atmosphére, increases its volume, and destroys a part of the equilibrium which there prevails. The atmosphere being then a little agitated, we feel a light and gentle breeze, which we call zephyr.

Lady Caroline.—Why, Edward, during the summer, is the rising sun frequently accompanied with a little wind?

Edward.—Because the heat of the sun, rarefying the air, forces it to occupy a greater space, and makes it fly to those places where it finds the least obstacle.

Lady Caroline.—How does it happen,

Sophia, that trees are less subject in winter than in summer to be broken by the violence of the wind?

Sophia.—The reason is, that in winter the trees, not being furnished with leaves, oppose less surface, and consequently give less power to the wind.

Lady Caroline.—Why, Frederic, are easterly winds so continually dry?

Frederic.—Traversing a vast quantity of land, and little sea, they are charged with very few vapours.

The western winds are humid; because, traversing many seas, they are loaded with vapours.

South winds are generally hot; because, blowing from a hot country, they bring with them vapours, exhalations, and agitated particles of air, naturally caused by a motion which in every direction produces heat.

The north wind is extremely cold, as it rushes from the coldest regions of the earth. It brings with it salts, nitre, and flakes of ice, which contribute to make these winds extraordinarily bleak; for if we place small pieces of ice in the nozel of a pair of bellows, there blows from them a wind more than usually cold.

Lady Caroline.—How, George, are certain plants produced on the tops of towers, trunks of trees, &c.

George.—The wind raises with the dust the seed, which shoots and buds forth. Cow-grass and other herbs frequently grow in places where we wish they should not; because their seeds being brought thither by the wind, afterwards vegetate.

Lady Caroline.—How, Kitty, are the wings of a windmill turned round by the wind?

Kitty.—Its four wings supply the place of levers, and present their planes in an oblique manner to the direction of the wind. The power which continually acts on these four inclined planes, forces them instantly to fly back; this is what they cannot do without turning, and making the axis turn to which they are fixed.

Lady Caroline.—How, William, does the wind raise paper kites into the air?

William.—The string by which they are held is tied in such a manner that their surfaces are always obliquely opposed to the direction of the wind; and then the impulsion of the air naturally tends to make them mount, by describing an arch of a circle, which has for its radius the twine that is held in the hand of the person who guides the kite.

Lady Caroline.—Why, Elizabeth, are the winds more rapid and more violent upon sea than upon land?

Elizabeth.—Because they encounter no obstacle upon sea; while on land they are continually interrupted by mountains, edifices, and thick woods.

THE

SIXTH DIALOGUE.

ON FIRE.

Sir Thomas.—WE are now, my dear children, about to enter upon a discussion of the nature, powers, and properties of Fire.

I shall, previous to the questions of Lady Caroline, lay down some definitions, which it is indispensably necessary that you be made acquainted with:

1st. Fire is a very subtile body, differing from all others known to man. Considered in its principle, it must be something more than the intestine motion of heated parts, or the actual dissipation of inflamed bodies; for in a natural state, all motion once impressed, slackens at last, and ceases to be perceptible, by being distributed to a greater quantity of matter. Fire, on the contrary, is communi-

cated with increase, and a spark becomes a conflagration.

Fire, considered in its principle, is true matter: First, because it has all the most essential attributes of it, such as extension, solidity, &c. Secondly, because it possesses the properties most common to matter, as mobility and gravity. This substance is a being separate from all others, and of which the nature is fixed and unalterable.

2d. Elementary fire should be considered as a fluid, but a fluid which never ceases to exist. It appears, that it is the origin of all fluidity, since, by the help of this element, the different parts of bodies are stirred up and separated from each other, when they partake of that respective mobility which distinguishes fluids from solid bodies.

3d. The matter of fire (which, besides, is the same as that of light) is the most subtile, the most penetrating, and the most elastic of all matters we are acquainted with. Nothing can resist it, and it resists every thing, except a copious quantity of water. A diamond, that by chance may have dropped into fire, becomes unpolished, its angles are blunted, and it loses its transparency. In fire, likewise, all mixed bodies are decomposed.

4th. Fire exists every where, and in all

things: it fills the vacuities that are left betwixt the particles of a solid or fluid body; and distends them, more or less, according to the immediate degree of its activity. The smallest portions of matter, of whatever species they be, excepting atoms, contain within them a proportional quantity of fire, which cannot get vent, or shine, until it shall have forced its passage through the body that contains it; but which will not take place until it shall have received a degree of force superior to the resistance by which it is restrained. Now, as parts of matter are, according to their species, more or less difficult to disunite in a mixed body, which is put into fire, the particles of a certain order will cede to the internal power which tends to dissipate them; because the degree of fire which actually reigns in the total mass, is sufficient to occasion this effect, while others will resist; not that they likewise contain an equal cause of disunion, but only that this cause has not received the fire that acts outwardly, sufficiently intense to produce this effect. Thus every thing is inflammable in this sense; salt and earth, which make the ashes of charcoal, and which are almost always presented under the form and colour of grey powder, would assume the redness of a burning coal, if we applied a degree of fire sufficient to animate that

which is retained in the fixed parts, and which would make its appearance on the surface. Even water would become burning, and shine like light, if the elementary parts which compose its particles, and which we also allow to be shut up within them, could be disunited with as much facility as the particles themselves relinquish the mass in order to evaporate.

5th. Some people think that certain bodies are more inflammable than others, because they contain more material fire; others believe that, this element being equally expanded in all bodies, a matter inflammable differs from another, not because it contains more fire, but merely that its own parts are of a nature yielding more easily to the action of fire, when excited; because, say they, all bodies, when they have been a sufficient time in the same place, assume the same temperature.

6th. There are two principal causes that may produce heat in bodies. The first is the presence of the sun, and the direction of the rays which it emits. The pores of bodies receive, by the presence of the sun, a new fire, in proportion as the incidence of his rays is more perpendicular. The second cause which manifests fire, is to put it into action, which interrupts the equilibrium to which it tends. In short, what gives to the parts of fire contained in bodies that

motion and appearance which they produce, is their friction against each other. Every known method of exciting and extracting fire, is only a modification of this second cause, which shews itself so much the more powerfully, as the bodies on which we exert the friction are closely applied to each other.

These definitions, preparatory to the questions that Lady Caroline is about to propose, I hope will have the desired effect upon your minds. I now, therefore, resign to her the task of examining you.

Lady Caroline.—Why, George, is the weight of certain bodies diminished by the action of fire?

George.—Because the fire dissipates a great number of their parts; for instance of water, &c.

There are, however, certain bodies whose weight is increased by calcination (burning to a cinder, or to powder); because there are mixed in these bodies, heterogeneous particles of the atmosphere.

Thus iron placed in fire increases in volume; because the fire, insinuating itself into its pores, rarefies and dilates the parts of it.

Lady Caroline.—Whence, Kitty, comes it that the particles of fire which we draw with the steel from the flint are so very small?

Kitty.—Tempered steel, which is very hard, is never impressed but with great difficulty.

The sparks that we perceive when we strike the steel, are round; because these small bodies which fall from the steel have been, for an instant or two, in a state of fusion; and such is the figure of all softened matters that are freely plunged into a fluid, as were these small particles of steel in the air at the moment of their scintillation or sparkling.

A magnetised knife attracts certain particles which we have carefully gathered together, and put into a paper, because, being very hard, they have been but simply melted.

The knife cannot draw the other particles, because by a more violent degree of fire they have passed the simple fusion, and are transformed into dross.

When we look at these small bodies through a microscope, we find some of them vitrified, and others like dross. This comes from the flint, which is struck in a sliding manner against the steel, and does not perhaps attack with an equal degree of force all the particles that it tears off. These particles themselves are some larger than others, and we may still suppose that the portions of fire which they inclose are not all equally disposed for action.

Lady Caroline.—How can the particles of steel in so short a time, and apparently by so slight a cause as the striking of the flint against it, redden, melt, and become dross, William?

William.—Because the steel and the flint contain a great quantity of inflammable matter; and the stroke, which does not appear very considerable to the eye, is immense, with relation to the small quantity of matter upon which it acts, and which it strikes off.

Lady Caroline.—The bamboo, a sort of Indian cane, when we rub two pieces of it together, produces fire in the same manner as the flint and steel. Give me the reason of this, Elizabeth.

Elizabeth.—The friction excites the sulphur which this body contains in great quantity, and breaks the little inclosures in which it is pent up.

Lady Caroline.—How does it happen, Henry, that by applying oil or grease to the iron-work of certain machines, they are prevented from taking fire?

Henry.—Because the pivots of large machines, the axletrees of the wheels of carriages, &c. unless properly greased, set fire by friction to the wood in which they roll. As the grease renders the surfaces more smooth and easy, they must consequently experience less friction; the fire, therefore, less agitated in its small recesses, does not so easily quit them. But in surfaces not greased, the friction always acts more strongly upon the fire, and brings it

forth, after having made its way through the obstacles that restrained it.

Lady Caroline.—The chisel, with which cold iron, or any other hard metal, is cut, becomes in time so hot, that those who use it are obliged to plunge it frequently into cold water to preserve its temper. Why so, Fanny?

Fanny.—The chisel is strongly pressed betwixt the two parts that it divides, which pressure is equivalent to the strokes of the hammer that the chisel receives on the two extremities of its edge.

All tools that are used for turning or perforating cold metals, burn the fingers of those who heedlessly touch them; for in this case they experience great friction. The particles of fire are put in motion in their minute retreats, through which they burst and gain their liberty.

Lady Caroline.—Horse-shoes, and the iron which girds the wheels of carriages, very often, by sliding, strike fire from the stones of the street. This does not happen when a piece of soft iron is struck against a flint. What is the reason of this, Mary?

Mary.—In this last case the friction is not so rough, nor the sliding of which you have spoken so continual. The particles of iron struck off by the edge of the stone, are evidently

too large to produce fire by the degree of heat which this friction excites.

A peasant who has nails upon the soles of his shoes seldom strikes fire like the horse, although he should slide as much as that animal, because the friction is not so considerable.

As it is not, however, impossible for soft iron to produce ill consequences, mills and magazines of powder are always removed as far as possible from every thing that might occasion fire, as the softest kind of iron would do when struck against street stones, gravel, &c.

Lady Caroline.—How, Edward, is the heat produced in a ball thrown from a cannon?

Edward.—By the fire which communicates the powder to the ball, from its friction against the sides of the cannon, and from its shock upon the stones or the ground on which it falls, and not from the friction of the air, since the most violent winds never heat any kinds of bodies.

Lady Caroline.—The degree of heat, Frederic, acquired by corn in grinding, is sometimes so intense as to burn it. How does this happen?

Frederic.—The mill-stones either turn with too great velocity, or have not sufficient room to play; in either case, the motion being too strong or rapid, simply to disunite the parts of

the grains themselves, communicates even to the fire with which they are impregnated; and causes the burning your Ladyship alludes to.

Lady Caroline.—When a person slips down from any height by a rope which he closely holds betwixt his hands, why, George, does he experience a friction that burns the skin, and raises blisters upon it, in the same manner as when we touch a too hot substance?

George.—Because the rope, by the successive asperities of its surface, agitates those parts of the hand which are applied to it, and the fire which these parts contain, irritated by the close and rapid friction, bursts out and produces this effect.

Lady Caroline.—When a person is agitated, or walks too long, and with too much speed, why, Kitty, does he feel very much fatigued?

Kitty.—Because then the limbs of the body have respective motions, which reciprocally act one against the other, and give a kind of heat which exceeds that of the natural state of the body; and this heat is accompanied or followed by the sensation of weariness.

Lady Caroline.—What is the reason, William, that friction has less effect upon fluids than upon solids?

William.—The particles of fluids being moveable, escape from the friction which is necessary

to put in action the fire contained in their pores.

Lady Caroline.—Why, Elizabeth, doe s the mixture of two different fermenting bodies become hot?

Elizabeth.—Because the parts of the two bodies strike against each other, rub, penetrate, and drive forth the fire contained in their small pores.

Thus, when three ounces of spirits of wine are poured rapidly upon a similar quantity of water, the mixture becomes heated; because the small particles of water are carried with force into the small masses of the rarefied spirits of wine, which are spongious and fit for being divided, dissolved, and extended in a liquor adapted to penetrate them. There is made a dissolution of spirits of wine by water, similar to an exact fermentation. The shock, the friction, the disunion of the parts which held the fire inclosed betwixt them, set it at liberty and produce the heat.

We see in this mixture bubbles of air that interrupt its transparency. These bubbles, which were lodged in the pores of the respective liquors, are driven out by the mutual penetration of the two masses. Dilated afterwards by the new degree of heat which results from them, they rise to the surface on account of their respective lightness.

Lady Caroline.—I have here, my dear children, an apparatus with which I am about to make an experiment.

You observe here are three-eighths of an ounce of new oil of terebinth, which I put into this large glass. I pour on it, at two or three different intervals, as you may observe, one-eighth of an ounee of good spirit of nitre, and as much oil of vitriol eoncentered.

You now perceive a very thick smoke, from which a flame issues to the height of sixteen or eighteen inches.

The vapours now having spread themselves, we smell a great fragrance, which, as they dissipate, beeomes more pleasant. Explain these effects to me, Henry.

Henry.—The essential oils of plants are very inflammable liquors, which chemists consider as a large quantity of sulphur, extended through a small portion of phlegm. The particles of fire which are contained there, as in other substances, are only enveloped and eonfined by the other bodies which contain more of them, and whieh retain them only in as much as it is necessary to animate their action. When a very sharp acid predominates in these oils, and when it penetrates them on all parts with precipitation, all the small portions of fire irritate by friction, and disengage themselves from the boundaries

which confined them before this dissolution; they then get their liberty, and burst out through every part. The most subtile parts of the mixture dissipate in flame; the more gross parts exhale in fume, which last produces the aromatic odour that so pleasantly regales our sense of smelling.

We know that vinegar dissolves coral, because its acids, penetrating the pores of the coral, invade and separate the parts.

But this kind of dissolution is not sensibly heated, because the particles of coral contain but little sulphur, and make but small resistance to the action of the acids; consequently there is scarcely any agitation.

Lady Caroline.—When spirits of nitre are poured over mercury, why, Fanny, do they produce an effervescence, an ebullition, and a sensible heat?

Fanny.—Because the acids of the spirits of nitre are introduced with vigour into the pores of the mercury, strike violently against the sides of the vessel, and expel the igneous particles.

Lady Caroline.—A mixture of volatile spirits of sal-ammoniac with spirits of wine, spirits of vitriol, and the oil of tartar, unite by coagulation. What cause, Mary, produces this effect?

Mary.—The acids, blunted or absorbed in

the alkali, form with it little particles which interrupt the motion of liquidity.

Lady Caroline.—Why, Edward, do we feel heat on our skin when we rub it with spirits of wine, or with any other liquid in which they are mixed?

Edward.—Because the particles of transpiration partake very much of the nature of water, or that of urine, which, mixed with spirits of wine, produce in either case a very sensible heat.

Lady Caroline.—What is the reason, Sophia, that pure spring water never ferments?

Sophia.—All its parts are homogeneous, and after a considerable evaporation, that which remains in the vessel is an assemblage of parts, less in number, but exactly similar to those which have evaporated.

Water sometimes corrupts, because then it is not pure, but contains a matter foreign to it, which adulterates and decomposes it, when the parts are stirred up by fermentation.

Lady Caroline.—In a corrupt, muddy, and stagnant water, Frederic, we often see many insects. Why so?

Frederic.—Because the fermentation made by the heterogeneous particles in the water affords sufficient heat to hatch the eggs of these different animals which the air has conveyed thither.

Lady Caroline.—Whence, Kitty, proceeds that little wandering meteor, called *Will with the Whisp?*

Kitty.—It is a small cloud of inflamed exhalations, or perhaps a small mass of phosphorus, which is the sport of the winds, and which continues to shine until the matter that furnishes inflammation be entirely consumed, or that the light that glimmers at a distance be extinct.

This little meteor is frequently seen in church-yards, in morasses, and in other soils that are of a flat and sulphureous nature, because from such places there arise many exhalations.

These fires hover before those who pursue them, because, as the person advances, he pushes the air which conducts them onwards. They pursue the person who flies from them, because the air which carries them on, seizes the spot which the person quits at every instant.

Lady Caroline.—How, Kitty, are those meteors produced which are vulgarly called *falling stars?*

Kitty.—By trains, or rather by small clouds which kindle inflammable vapours, and of which the light takes a certain direction, and a certain degree of vivacity, according to the position and nature of the substance that produces the light. These different bodies being inflamed,

their fermentation creates a light, which becomes visible under the form in which we see them.

Lady Caroline.—To what must we attribute those little meteors or lights, which, when the wind is tempestuous, are seen clinging to the cordage, masts, and yards of ships? Can you tell me, William?

William.—I have heard some well-experienced masters of ships assert, that this phenomenon is very common; that these luminous bodies are called Castor and Pollux, and are found to be nothing but a small kind of slimy and glaring fish, which are thrown up by the waves at the same time as the froth of the sea, and scattered on different parts of the ship.

This, Madam, I think very probable, since many sorts of fish, when placed in the dark, give a clear and shining light, similar to that of phosphorus.

Lady Caroline.—Can you, Elizabeth, explain to me the nature and substance of thunder?

Elizabeth.—It is a mixture of exhalations, subject to inflammation by fermentation, or through the shock and pressure of the clouds, which the winds agitate and violently impel against each other.

When a considerable number of these bodies

take fire, an explosion instantly follows, stronger or weaker, according to the quantity or nature of the inflamed substance, and in proportion to the greater or lesser obstacles that oppose their sudden expansion.

If the inflammation consist but of a small quantity of matter, and is confined to the surface of the cloud, this effect will take place without any noise, at least without any that can reach our sense of hearing; the result being only a sudden flash of light, nearly like that of a quantity of powder when set on fire, and which we see blown up from afar, wholly free and unconfined. It is called lightning, and in this instance flashes without any noise.

Lady Caroline.—What do you understand, Henry, by the thunderbolt?

Henry.—It is an inflamed vapour which bursts the cloud, sometimes at the top, sometimes at the bottom, or on its side, then darts with a velocity proportioned to its explosion, as the powder which is inflamed in a bomb directs its action, and discharges its contents, against every thing that surrounds the spot on which it falls. At every clap of thunder, the bolt issues forth, which is always preceded by lightning; but it only strikes terrestrial objects when it flows in a direction that leads to them.

Lady Caroline.—Whence, George, comes the

bolt, which descends with inexpressible velocity, inflames, melts, and consumes every thing it touches?

George.—It is the effect of a violent explosion, and of a fire which surpasses all the ideas of man. The matter of the bolt, always of the same nature with that of lightning, differs from it only by being driven from the cloud before it makes its explosion.

Both men and animals perish by the stroke of a bolt, without leaving one trace of the cause of their deaths, or any mark by which it may be known how they have lost their lives: this may proceed from the vapour of the fiery sulphur which is, to animals of every kind, when large enough in quantity, a most instantaneous poison. It is also probable, that when the bolt bursts forth, the air of that place at the same time ceases its elasticity. Animals then finding themselves in a void, die in the same manner as they would were they shut up in the recipient of an air pump.

When it thunders, certain fluids cease to ferment, such as wine, beer, &c. whilst others, which were not agitated before, begin to ferment; the reason of this is, because the motion that the thunder bolt produces, disturbs and deranges that fermentation which the parts of the fluid had before the storm, and makes it cease;

on the contrary, of those fluids which did not previously ferment, the parts begin to be agitated, and to ferment.

Milk, cream, &c. very often coagulate in dairies, and even beer is sometimes spoiled, as soon as it has thundered, because the agitation excited in the air affects these bodies so forcibly, that they can neither separate nor fall to the bottom, which last is absolutely necessary to the milk, in order that the cream may rise.

The rain that falls during thunder is more fertile than any other, because it is loaded with sulphureous, oleaginous, and saline exhalations, which are peculiarly favourable to vegetation.

Sir Thomas.—Before we quit this subject, my children, I have a few observations to make.

In the first place, if between the lightning and the explosion, the pulse beat six times, the bolt is about six thousand feet distant. In the second place, if it beat five times, the bolt is five thousand feet distant. In the third place, if it beat four times, it is four thousand feet distant, and so on. For the sound which comes successively, and from the place where the thunder is, departs at the same time as the lightning; and, according to the most accurate experiments, it makes about a thousand feet during the beat of one pulsation, or in one second of time; if, therefore, the explosion imme-

diately follows the lightning, the thunder impends over head, and danger is very near.

Lady Caroline.—Why, Kitty, is the clap that follows the lightning usually succeeded by a shower of rain?

Kitty.—The inflammation that causes the report separates part of the cloud, which then descends in rain.

When it rains very violently, it scarcely thunders at all, because the exhalation bears away the greatest part of it.

Lady Caroline.—When the bolt falls, William, why is it that different fires seem darting all at once?

William.—Because the exhalations issue from different parts, or the resistance of the air separates it.

Thus long streams of fire are seen which touch the earth and the cloud at the same time; because the strong impression which the fiery disturbance makes upon the sight, when it shoots from the cloud, still subsists, though it be far removed, and appears to be where it really is not.

Lightning winds in its descent like the angular foldings or breaks of a silken string or riband, when fluttering in the wind; because the centre of gravity is not in the centre of the figure, and the different parts of the inflamed exhalations do not strike the air with equal forces.

This is what makes it rush forth in serpentine lines.

Lady Caroline.—How, Elizabeth, can a person make a spiral line run round a perpendicular glass, so that one oblique side of the glass may be taken from the other oblique side? that is, it separates wherever this line has been drawn. How, I say, is this performed?

Elizabeth.—I really, Madam, do not know.

Lady Caroline.—I will then explain both the experiment and the cause; to which, my dear chidren, you will all of you attend.

I have here an exact cylindrical tumbler, on which Sir Thomas has been so good as to draw, from a point in the rim, a spiral line round the circumference of the glass to the bottom, with Indian ink. I now take this pointed common match, and dip it into a small earthen vessel of melted sulphur, about an inch above the point. The match, now dry, I put gently to the surface of this lighted candle, but avoid, as you must observe, putting it to the top of it, lest the vapour touch it, which would spoil the experiment. I have, as you may see, fastened the glass firmly to the table. I now light the match, and place it exactly upon the part of the rim where the spiral line commences. You now see that it uniformly keeps the same burning, and how steadily my hand goes with it over the line, till I come to

the bottom of the glass, which I shall allow to stand for a few minutes, till the sulphur may have thoroughly penetrated the line.

Now I take the glass gently by the top and the bottom, and you see how easily it comes asunder in the very part where the line has been described.

You cannot but be pleased, my dears, with this part of the experiment: I will now perform the other part of it, which is that of re-uniting the glass.

I place the two divisions of the glass together, exactly as they were before their disunion, and press them lightly. I take this cup of wine and pour it into the glass, and not one drop will run through it, so very closely has it again joined itself.

Sir Thomas.—Why, Henry, does the heat cause the liquid in the thermometer to ascend?

Henry.—It dilates the liquors, which consist, in one tube, of mercury; in the other, of spirits of wine; as, on the contrary, the cold which condenses them makes them descend.

After a cold wind has made these liquids descend, by their being exposed to the open air, if the tubes be covered with snow, they re-ascend, because the snow is less cold than the wind.

Lady Caroline.—I divide this walnut shell, Fanny, exactly in two, in which I place a six-

pence, and a mixture, consisting of three parts of nitre, or fine salt-petre, well pulverized, and dried upon a shovel, over the fire; to which I add two parts of flour of sulphur, and as much raspings of touchwood. On setting fire to this preparation, you see the six-pence melts into a fine white liquid, and the half shell of the walnut is just as it was before I placed it with the ingredients upon the fire shovel. Explain all this.

Fanny.—The action of the fire is only of short duration, but has time to penetrate and melt the six-pence, which is attacked at the same time in all its parts; for I observed that you placed the money in the middle of the mixture. With respect to the half shell, the fire has only had time to act upon the internal surface, which is a little singed. The great porosity of the half shell made the passage of the fire so free to it, that it dissipated without setting fire to any of its parts.

Lady Caroline.—Why, Mary, when we put a lighted candle into the smoke of one which has just been extinguished, does it light again without the wick having touched the flame of the lighted one?

Mary.—The fire of the lighted candle gives to the particles of the greasy vapour of the smoking candle, a small degree of fire, which

immediately re-lights it. For smoke differs from flame only in as much as it has less heat than the latter.

Lady Caroline.—Butter, and other fat or greasy substances, Edward, that are melted in kitchens, boil very quick, and with a great deal of noise. How does this happen?

Edward.—Because these kind of substances are almost always mixed with particles of water, or with the juice of herbs; and as soon as they have attained a certain degree of heat, the humidity which they inclose is converted into di lated vapour, and forms a great number of small bubbles, which produce that crackling noise which your Ladyship alludes to.

Lady Caroline.—If the flame of a large lighted candle be put into a thin glass tube of about seven or eight twelfths of an inch diameter, and about four inches long, it immediately lengthens and extends itself very considerably, having almost as much volume at the top as at the bottom. What is the reason of this, Sophia?

Sophia.—It retains its heat better in this tube, which heats itself, and like the air that continually renews itself, the inflamed particles remain longer in this situation.

Lady Caroline.—Whence, Frederic, proceed all those colours which appear in faggots and bundles of wood, when set on fire?

Frederic.—The colours of flames vary according to the different substances which are burned. Pure spirits of wine, and in general those which are extracted from all vegetables, give a clear, white, lambent flame; those of oil and other greasy substances give a bright jonquil, and those of sulphur, blue. When a body containing all these is set on fire, the flame that rises from it has more or less of all these hues, and besides has mixed with it black, which proceeds from the smoke and vapour.

Lady Caroline.—Is there nothing, George, but active air that can animate fire?

Would not any other fluid which was not too dense, or a vapour that flowed with great rapidity, do the same?

George.—Yes; for if the flame of a flambeau, or a large lighted piece of coal, be appplied to the pointed end of an æolipile, in which water has been made to boil, the vapour that issues from it has all the effect of a pair of bellows. We cannot attribute this to the vapour containing any *air*, since it has been perfectly driven from it by the fire that heated the water.

Lady Caroline.—Why, Kitty, do we experience great warmth in cellars, caves, &c. during winter, and in summer quite the contrary?

Kitty.—They only appear so by the difference hat there is betwixt their temperature, which

is always nearly the same, and that of the air we leave when we enter into these subterraneous places. Common experience obviously proves this: for if we have one hand very hot and the other very cold, and we plunge first one and then the other into a pail of cold spring water; this water will, without doubt, feel very warm to the cold hand, but extremely cold to the warm one.

Lady Caroline.—It is said, William, that a person having rubbed his hands with the juice of onions, may dip them into melted lead, or handle red-hot coals, without the least danger of burning them. Can you explain this?

William.—The juice, which covers the main skin, and fills the pores of the surface of the hand, hinders these burning substances from seizing and spreading upon the hands. Instead of this, however, an equal mixture of spirits of sulphur, sal-ammoniac, essence of rosemary, and juice of onions, might be used; which would enable any of us to hold red-hot iron in our hands without burning them, to the great astonishment of all who behold us, and who are unacquainted with the means by which we effect it.

Lady Caroline.—Why, Elizabeth, do we feel so much refreshed by cold bathing?

Elizabeth.—Because the agitation of the

blood, of the spirits, and of the insensible parts of the body, communicate to those of the water, which, being colder than our bodies, receive the excess of heat which their different parts communicate to them.

Lady Caroline.—Why, Henry, do frozen fruits and vegetables resume their former state on being put into cold water in a warm place?

Henry.—Because the cold water gives to their particles a moderate agitation, and the fibres nearly taking their first situation, receive no damage.

These same fruits would spoil were they placed near the fire, because it would melt their frozen juices too quickly, and at the same time would break and alter the fibres, and thereby render the fruits insipid.

Lady Caroline.—How does it happen, Frederic, that when I take a leaden bullet, and wrap smoothly round it a piece of paper, and hold it with these small tea-tongs over the lighted candles, the lead melts, and falls drop by drop through a little hole that it has made, without burning the rest of the paper?

Frederic.—It is owing to the action of the fire, which passing freely through the large interstices of the paper, with which it always abounds, does not burn it; but finding resistance in the close particles of the lead, it insinuates

itself amongst them, and melts it, while the paper remains just as it was.

Lady Caroline.—Can you tell me, Edward, the cause of earthquakes?

Edward.—The inflamed matter, prodigiously rarefied in deep caverns, not being able to make a free issue, shakes and raises the superimpending regions; like a mine, which, when the powder of it is set on fire, struggles for vent, and when it gains it, blows up the earth that it was covered by, with terraces, ramparts, towers, and citadels.

Earthquakes, Madam, are frequently accompanied by formidable fires. I recollect Sir Thomas having read to us, that in the year 1677, an earthquake was universally felt through the whole of the Canary islands; and that there were seen torrents of stones and fire issuing from the bosom of the earth in the midst of loud thunder, which rebounded through every island.

Lady Caroline.—How does it happen, Henry, that the water in wells sometimes becomes suddenly troubled, sulphureous, and of a bad taste? Whence also come subterraneous roarings, and the sudden elevation of billows in the ocean, at a time when perhaps the weather is serene, and the heavens appear tranquil?

Henry.—These are commonly the effects of subterraneous fires, and consequently alarming

signs, as threatening the neighbouring parts with an earthquake.

Lady Caroline.—New islands have been frequently known to appear suddenly. How, Sophia, is this caused?

Sophia.—The subterranean fires dilate, swell, and heave up the earth at the bottom of the sea, and sometimes divide upwards of three hundred and sixty feet of water: the earth thus raised forms one or more islands.

Lady Caroline.—Why, George, are some lakes frozen even in the greatest heats of summer?

George.—Because they are situated in places that contain great quantities of nitre and saltpetre, which freeze the water, and of course hinder the melting of the ice.

Lady Caroline.—When the lighted end of a candle is turned downward, or plunged into inflammable liquors, it is extinguished; and green wood, slightly set fire to, if the burning be not kept up by other wood that is more dry, likewise goes out. What is the reason of this, Mary?

Mary.—The fire in either case does not want for aliment; but in the first, this aliment has not sufficient time to heat, and in the second it cannot on account of the humidity which it contains.

Lady Caroline.—Why, Elizabeth, has the flame of a candle more diameter than the cotton?

Elizabeth.—Because the fire pushes out the particles of tallow, which are composed of oil, water, air, salt, and *caput mortuum.* These bodies dilated by the heat must of necessity occupy more space.

Lady Caroline.—What occasions the bubbling of boiling water, Kitty?

Kitty.—The first bubbles may be attributed to the air, which, dilated by the fire in the pores of the water, rises into bubbles and lifts up the aqueous particles: but as there is not a sufficient quantity of air in the water to produce all those bubbles which are perceptible in it when it boils, even to dryness, one should think that the vessel receiving by the place which the fire touches, more heat than the water can support while it is in the state of a fluid; the first layer which is applied to this too hot part of the vessel, is converted into vapour; and that many similar portions of vapour, dilated by the force of the fire which penetrates the vessel, roughly push forth the mass which on all sides environs their parts, and by their lightness gain the surface, where they dissipate.

Lady Caroline.—Why, Mary, does fire always ascend?

Mary.—Because it is specifically lighter than the air.

Lady Caroline.—Why, Frederic, does a squib always mount upwards?

Frederic.—Because as the action of the powder towards the breach of a gun or cannon, makes it recoil, so the action of the powder which pushes the squib upwards, finding no vent in the upper part of it, makes it recoil and mount.

Lady Caroline.—How does an artist, Henry, when he pleases, send off a squib parallel to the horizon, and make it return on its own track?

Henry.—By placing a small wheel, and a plane of wood, in the middle of the cartridge, of which the two extremities are open. Near the wheel, the artist makes a hole communicating with a little channel which is terminated at one end of the squib. At one end, he fills with the usual mixture the half of the cartridge up to the wheel; at the other end, he fills in the same manner the other half. He then ties to the squib thus charged, a couple of iron rings, or a wooden tube, through which he passes a rope stretched horizontally; he then sets fire to it at the first end. The powder inflamed, pushes the squib towards its other extremity which resists: the squib darts up like those that mount; and the horizontal cord directs it parallel to the

horizon: the powder being consumed up to the wheel, or to the little plane of wood, the fire penetrates through the small channel to the other end, which now takes fire. The action of the inflamed substance is felt against the wheel, which resists; the squib recoils, and returns rapidly the very same way that it set off.

Lady Caroline.—When vent is given to a mine of powder, Edward, why is the effect of the fire lost?

Edward.—Because as bodies in motion follow the direction where they find the least impediment, the powder set on fire in the mine that has vent, exhales in part through the free issue that it finds. The more it exhales, the less effort it makes against the vault and the solid parts of the mine.

Lady Caroline.—How, Fanny, is the tallow of a lighted candle conveyed to the flame which is above it?

Fanny.—1st. Because the threads of cotton which form the wick, and which are twisted, perform the office of a sponge, or of capillary tubes.

2d. Because the *air* being extremely rarefied by the fire in the superior part of the wick, the pressure of it downwards must cause the melted particles of tallow to mount up towards the fire.

Lady Caroline.—Why, Frederic, do glass vessels of every kind break when boiling water is poured into them too suddenly?

Frederic.—The igneous parts exerting every effort to penetrate the glass, strongly dilate its external surface before that within can be proportionally extended, and this occasions a solution of continuity.

Lady Caroline.—How is it, Elizabeth, that fire, instead of dilating certain bodies, condenses them; such as the dirt of the streets, clay, and bones?

Elizabeth.—It dissipates many particles which render them more soft, as those of the water, &c.

Lady Caroline.—Why, Kitty, do liquids dilate by heat?

Kitty.—Because the fire penetrates, disunites, and raises the particles of the liquid mass.

Lady Caroline.—Why, George, are the chords of a harpsichord, or piano-forte, deranged, when the temperature of the place where it stands in a certain degree varies?

George.—Because the chord of an instrument which lengthens by heat, consequently becomes less tight than it was, if the fixed points by which it holds do not remove from each other in proportion to that lengthening; and a sonorous chord, allowing every thing else to be

equal, is of a more acute tone according to its degree of tension. Thus, the chords of these instruments, partly iron, and partly wire, differently lengthen betwixt themselves, in the same degree of heat, and all of them much more than the wood of which the bodies of the instruments are made, and upon which the pegs and bridges are fastened.

In the same manner all solid bodies, such as marble, stone, brick, glass, metal, the bark of vegetables, bones, leather, and the horns of animals, diamonds, instruments of every kind, furniture, wainscots, and buildings, all dilate by heat and condense by cold.

Lady Caroline.—Why, Mary, do farmers take care to dry hay well before they house it?

Mary.—Because by this precaution the most volatile parts of the plants exhale, and produce no fermentation. When farmers neglect drying it, it acquires a bad taste, and is heated, sometimes so much as to take fire, which often causes dreadful conflagrations.

THE

SEVENTH DIALOGUE.

ON WATER.

Sir Thomas.—WATER is a humid fluid, without taste or smell, and generally extinguishes fire when this last is not too powerful for it.

Natural philosophers differ very much upon the subject of the formation of ice. According to Descartes, the defect or diminution of the motion of water is the cause of congelation; and repose alone is sufficient to unite the parts of it so as to form a hard body.

Rohault, and most of the Carthesians are nearly of opinion with Descartes. They believe that it is the motion of subtile matter that makes water liquid, and that the defect or diminution of motion converts it into ice.

Claudius Perrault contended, that bodies become liquid through the interposition of certain volatile parts, called common corpuscula, which flow and pass through them; and that when a cessation of this flowing takes place, these bodies are no longer liquids. They harden by reason of the weight of the subtile portion

of air compressed in the grosser particles of them, applied one against the other.

According to the system of Jean Baptiste Duhamel, the only difference betwixt water and ice is, that the particles of the first are agitated by a very subtile matter, and that those of the latter remain immoveable, and rest one upon the other.

The hypothesis of Hartsoeker is, that water is changed into ice by the absence of fire, and that it again becomes water on its return.

According to the celebrated Boerhaave, water is never without fire, and that in a very great quantity. If fire diminish in the thermometer only to the thirty-second degree, the water becomes ice. Water, then, in its natural state, is only a species of glass, which is melted by the thirty-third degree of heat, and again frozen by a very little greater degree of cold.

The illustrious Gravesand has recourse to attraction, to explain the formation of ice: "Water," says he, "is only melted ice; and it is liquefied by heat, which naturally changes solids into fluid bodies" If water be destitute of the fire which dilates it, its particles re-unite, drawing themselves to each other, and are transformed into ice. If ice be penetrated by fire, its particles acquire a repulsive force; they

then move, separate themselves from each other, and become a perfect fluid; that is, water.

A strange substance is introduced by Musschenbroek for the formation of ice. The want of fire, the repose of the parts, even attraction itself, which he, besides, admits of, are not sufficient in his opinion to turn water into ice. There are in the air, as he pretends, certain frigorific particles, which insinuating into the water, make it change into ice. If it freeze very hard, the reason is, that the air is full of these particles; if but little, there are only few of them in the atmosphere. It freezes often without being cold, and frequently produces great cold without freezing. When we demand of this philosopher, what these frigorific particles may be, he fairly owns that he does not yet know them, but that they may be known some time or other.

By the help of certain principles founded upon the nature and properties of bodies which change into ice, De Mairan has undertaken to explain how, and by what mechanism such a change is effected.

"Would you," says he, "make ice, that is, change a liquid body, such as water, into a solid body, drive out a part of the subtile matter which flows betwixt its interstices; diminish its motion, or weaken its spring in such a man-

ner that it may no longer overcome the resistance of the integrant parts of the liquid, by all of which cold is produced, and you will have ice.

"On the contrary," continues he, "would you change a very hard body, such as glass, bronze, &c. into a liquid body, introduce a sufficient quantity of subtile matter into its pores, or increase the motion and spring of that which is contained in it, that it may separate the parts that are united by their surfaces, and disembarrass those that are entangled by their branches; you will then do what is done by the heat, and have a liquid or thaw. It is to the rays of the sun that this alteration of heat and cold must be attributed, which we experience according to different circumstances. Thus, the distance of this heavenly body, the obliquity of its rays, and the quantity of air or of vapours which they may have to traverse, are the most general causes of the diminution of motion, of spring, or of quantity of the subtile matter contained in liquids, and consequently of their congelation. Other causes which may still weaken the activity of this matter, are either a subtile nitre, which sometimes spreads itself in the air, a dry wind, or the suppression of hot vapours, which exhale from the bosom of the earth."

Thus, my dear children, I have given you the different opinions of the greatest philosophers upon the subject of the element about which Lady Caroline is going to question you. I leave every one free to adopt that which may appear the most natural and the most feasible; but at the same time I must acquaint you, that I am inclined to adopt that of Hartsoeker, for its simplicity, probability, and apparently incontestable truth.

Lady Caroline.—Why, George, is water a fluid?

George.—Because the particles of fire with which for the most part it plentifully abounds, in temperate climates, support the respective mobility of its parts, and thereby render it a fluid body. These particles of fire penetrating the water, set its parts into a state of flowing one upon the other, and to obey the inclination of their own weight, or any other impulsion. But, independent of this general cause, we may say, that water is more fluid than many other liquids, because its particles are extremely small, and of a form apparently very fit for motion, being spherical.

Lady Caroline.—Why, Kitty, does not cold water penetrate bodies with as much ease as that which is heated? and why does this last raise more quickly to its surface bodies that ad-

here to it? Why is the solution of salts more quick and effectual as the degree of heat is greater? and why do we cook victuals and fruits in boiling water, and not in that which is cold?

Kitty.—Because all these bodies, dilated by heat, become more penetrable, more easy to separate, and even the water itself, animated by heat, becomes the more active for it. Add to this, that the same heat, subdividing the particles of water, makes them more fit to insinuate themselves into substances that are dissoluble.

Lady Caroline.—Whence, William, originate fountains, wells, rivers, and all those current waters that are constantly renewed?

William.—From rains, snows, mists, and, in general, from all vapours which exhale both from continents and islands. There, are, however, some fountains which owe their immediate origin to the water of the sea; but then they are generally close to its borders.

Lady Caroline.—Since the water of the sea is salt, Elizabeth, how happens it that sweet fresh water is found even upon the very coasts of little islands?

Elizabeth.—It is the rain, and not the sea that produces these waters; hence they disappear in dry weather.

Lady Caroline.—Waters that rise from the bosom of the earth, Henry, are almost always fresh. Why so?

Henry.—Because these waters, in rising into vapours, similar to those that constitute the clouds, quit the salts with which they are charged, and every other heavy substance that might volatilize like them.

Sources that border near to the sea are likewise as fresh as those that are much farther removed from it, because they all owe their origin to the waters which descend from the atmosphere, and there never ascends to this a single exhalation that is not perfectly free from every saline particle.

Lady Caroline.—How is it, Fanny, that springs are more commonly found at the bottoms of mountains than in any other place?

Fanny.—These large masses being elevated in the atmosphere, impede the clouds, present more surface to the rains and the mists, and are for the most part covered with snow, which dissolves gradually, and produces perpetual flowings, the greatest part of which remain hidden either in rocks or in the earth, and shew themselves only in places situated very low.

Springs are found even upon the tops of mountains; and they are known to come from others still more high; if there be a valley be-

twixt these mountains, the water is conducted from the highest to the summit of the lowest, by subterraneous channels, like communicating and curved tubes which carry water from reservoirs to places the most elevated, down to the issue which lies the lowest, and allows it to escape in form of a spring.

Lady Caroline.—Why, Mary, are there found in remote places, fountains of salt water that are subject to ebb and flow?

Mary.—They flow immediately from the sea, which, agitated and raised by the tempest and the flood, may, by falling back, impel its salt waters, and raise them through subterraneous channels into reservoirs formed above the level of the springs.

Lady Caroline.—Why, Edward, in the heats of summer do we see fountains entirely dried up?

Edward.—Because their subterraneous waters flowing too near the surface of the earth, are absorbed in the great heats, by the extreme drought of the soil. Besides this, a spring may be dried up by an earthquake, which, deranging the channels of the water, will force it to take another course.

Waters are less subject to dry up, and are more fresh and pure, when the channels that convey them to the surface of the earth are dis-

tant from them; because then they are less agitated, and less affected by the external air and the heat of the sun.

We find at great distances from the sea, springs of salt water; because the waters of these sources have passed through some mine of salt, of which they have carried off a great quantity of the particles.

Some fountains petrify certain bodies, because their waters are charged in the earth with grains of sand and extremely minute stones, which sinking into the pores of the bodies that encounter them, through the agitation of the waters, immerse them without their being able to disengage themselves. These bodies then become more massive, more solid, and harder. Hence the name of petrifying fountains.

There are some rivers which in twenty-four hours change iron into copper, and fountains that require only five or six hours to change copper into iron. The reason is, that their waters in different mines have impregnated themselves with particles of copper or of iron, which, penetrating like little wedges, inserted and fixed in the interstices of the bodies, detach a great quantity of their particles from them, of which they assume the place, and become either iron or copper.

Lady Caroline.—There is, Sophia, at Senlis,

a village near Chevreuse, in France, a public fountain, the water of which causes the falling out of the teeth without pain or bleeding. How can this possibly happen?

Sophia.—It may perhaps result from this water passing through nitrous and aluminous places, and by this means becoming loaded with spirits of nitre, with long, round, and pointed corpuscula, which may easily separate the teeth from the roots, and be the cause of the effects produced by this water.

Lady Caroline.—It is related by travellers, Frederic, that there is a fountain in China, the water of which towards the top is very cold, but so hot at the bottom, that a man can scarcely bear his hand in it. What can be the cause of this?

Frederic.—This water must flow through oily places, where it becomes impregnated with the corpuscula of oil, acids, salts, and alkalis; all of which are adapted to ferment together. It then becomes heated; and the cold towards the top, when the bottom is hot, proceeds from the fine particles being agitated and worked up to the surface, which very easily dissipate in the air; and that those of the bottom, being retained and kept down by superior ones, unite their forces, and hence produce the agitation that causes its heat.

Lady Caroline.—It is said, George, that the waters of some fountains are cold by day and hot in the night. How can this happen?

George.—The heat of the day renders the particles of the vapours and exhalations too minute, and too soon dissipated to cause any sensible agitation: the cold of the night, on the contrary, condenses and re-unites them, and thereby puts them in a state of giving to the sense of feeling, by their agitation and violence, sufficient power to cause the heat that is then experienced.

Lady Caroline.—There is a fountain in Germany that emits fire to the height of three feet, as soon as fire is held one foot above its surface. What is the reason of this, Kitty?

Kitty.—The light spirits and volatile particles of sulphur and bitumen, with which in its course it becomes charged, rise, flutter upon the surface of the fountain, and in taking fire at the approach of the flambeau, spread flames over the top of the water.

The same thing however cannot happen if any portion of the water be removed from its original situation, because the sulphureous particles exhale and dissipate in the agitation of such a motion.

Lady Caroline.—Why, William, are certain fountains intermitting?

William.—If the rays of the sun, interrupted by the points and prominent parts of rocks, give many checks to the snow which supplies the waters of some sources, this snow, melted at different intervals, must produce interrupted flowings, or intermitting sources.

Lady Caroline.—Experienced miners, Elizabeth, have almost always remarked, that wherever they found water under ground, they likewise had air with it; but when this last failed, they could no longer draw breath, and that their lights went immediately out. Whence can this air proceed?

Elizabeth.—The apertures that introduced the water, at the same time admitted the air with equal liberty.

I have read that the same workmen, in many mines, smell very far below ground the sweet odours of flowerets and shrubs; because the waters that have washed the mountains and bathed the meadows in the season of their blooming, flow afterwards under ground in hollow tracks, and charge the air that they bring with them, with the spirits of odoriferous herbs over which they have flowed.

Lady Caroline.—Why are the waters of many public bathing places found hot? Tell me, Henry.

Henry.—This heat comes from fumes or sub-

terraneous vapours, such as may be perceived in the bottoms of very deep mines; or from some mixture of minerals, as iron or sulphur, which, by their reciprocal shock, excite, in rolling with the water, the fire which they contain.

Lady Caroline.—Why, Fanny, does not a mineral water heat as quickly over the fire as common cold water?

Fanny.—Because the heat that the mineral water brings from the bosom of the earth consists only of light vapours, which the impression of the fire at once dissipates.

Mineral waters do not burn the tongue, although common water heated to the same degree as these, burn it: this is owing to the vapours that produce the heat in mineral waters being more fine than the particles of common water, which have less power to separate the parts or fibres of the tongue. Mineral waters that are loaded with sulphureous parts, may spread upon the tongue plentiful layers of them, which render it inaccessible to the heat of these waters.

Mineral waters, however, that do not burn the tongue, burn the hand, because the sulphureous particles do not so easily adhere to the hand; or, on account of the different texture of the pores, the hot vapours insinuate

themselves with more violence into those of the hand.

Lady Caroline.—Whence, Mary, arise the salutary effects of mineral waters?

Mary.—From the different particles with which they are charged, calculated to render the blood clear, facilitate its circulation, and dissipate obstructions. Certain mineral waters are pernicious, because they contain corpuscula of a quality to tear the fibres of the body, to thicken and stop the blood, and to cause obstructions.

Lady Caroline.—How happens it, Edward, that fresh water is sometimes found at the bottom of the sea?

Edward.—This water is that of certain rivers which are brought into the sea through subterraneous passages.

Lady Caroline.—In certain rivers, Sophia, are found small spangles of gold, silver, &c. Whence come they?

Sophia.—The water, in passing through different mines, becomes charged with these bodies.

Lady Caroline.—Why, Frederic, does the Nile regularly overflow Egypt?

Frederic.—According to the observations of travellers, Abyssinia, where the Nile takes its

source, is full of mountains. It constantly rains there from June to September. The vapours raised at this time by the heat of the sun situated in our tropic, are carried towards these mountains by the north winds, are re-united into large drops by the cold of the same mountains, and there fall in rain. During this time, the Nile receives streams, torrents, and rivers, which, overflowing, pour down from these mountains; it then swells to a prodigious height, and at last, by its inundation, moistens the soil, waters the face of the whole country, and deposes there its salts and fat rich earth; which occasion the peculiar fertility of Egypt?

Lady Caroline.—What causes the saltness and bitterness of sea water, and occasions sea-sickness, George?

George.—It proceeds from the salts which the rivers and floods bear away with them, and from salt mines that are frequently found at the bottom of the sea.

The bitterness of sea-water may be attributed to the bitumen with which it is impregnated; since it is no longer so when this is taken away.

On sea we experience great sickness, and agitation of the intestines, because the corpuscula of salt and bitumen too strongly act upon the body, disturbing the internal parts, stop-

ping the course of the spirits, and distending the fibres.

Lady Caroline.—In sea voyages, Kitty, fresh water alternately corrupts and purifies; in the course of three months, this change takes place three times. When it spoils, it is full of small worms; when it becomes again sweet, these worms disappear: and every time that it spoils, a new species of insect is seen in it. Account for this.

Kitty.—The fresh water which is put into the barrels, is charged with the eggs of various insects. The heat of the vessel hatches them; they become a swarm of small worms, and hence the water is spoiled. Soon after this they die, and the particles of them, separating, are lost in the water: it then becomes sweet by resuming its first state. After this, the heat gives rise to others, from the eggs of another species of animals, which require a certain degree of time and heat, as did the first: the water is then spoiled a second time. These likewise very soon die, and the water resumes its former goodness. The heat then produces a third kind of insect; and hence the succession of different animals, and the vicissitudes of corruption and purity of the water.

All this however may be prevented by throwing into a barrel of fresh water a very small

quantity of spirits of vitriol; or rather by washing it in hot water, and burning in it a small piece of sulphur before it is filled; because spirits of vitriol and sulphur render these eggs fruitless, kill the inseets before they appear, and preserve the water perfectly fresh during a long voyage.

Lady Caroline.—Whenee, William, arises the different taste we experience in rain-water (though caught in very clean vessels, without having passed over the roofs of buildings, or through gutters) when compared to any other?

William.—From the heterogeneous particles that it imbibes in the atmosphere, which is always more or less charged with different exhalations.

After having settled, it improves and becomes more like other water; because if it be not covered up, it purifies itself in a very short time of its heterogeneous particles, the greatest part of which are extremely volatile.

Lady Caroline.—How does it happen, Elizabeth, that the heat of the water upon the summit of a mountain is less sensible than that in a plain, or in any other situation that is lower?

Elizabeth.—From a smaller quantity of fire being requisite to heat water, when it is less pressed by the weight and spring of the air. Now, upon the mountains, the air being more rarefied than in lower situations, it makes less resistanee to the fire, and gives it a freer pa sage; while that

of valleys making a greater effort against the column of air, which is higher and consequently more heavy, re-assembles and acts with so much the greater force upon the water.

Lady Caroline.—When a certain quantity of salt is thrown into a vessel full of water, how happens it, Henry, that this last does not run over the brim?

Henry.—Because the particles of the salt lodge themselves in the pores of the water, and occupy only those parts of the fluid where vacuities were found, or which were only filled with bodies foreign to the water.

Lady Caroline.—If five or six ounces of pulverized sal-ammoniac be mixed in half a pint of pure fresh water, in proportion as the salt dissolves, the water becomes extremely cold. Why so, Fanny?

Fanny.—By the reciprocal penetration of the water into the salt, and of the saline particles into the pores of the water, the parts of fire are driven about for some time; which, in whatever it consists, slackens this species of motion, and depends entirely upon itself for production and existence. This authorises the conjecture that there are certain cold fermentations which exhale from hot vapours, and which by this effect seems to indicate that fire strongly chased from bodies that mutually penetrate each other, carries off with it the most subtile parts of them.

The sea is salter in hot than in cold countries, because the water holds so much the more salt infusion as it is warmer.

It is sufficiently obvious, that the pores of this fluid, dilated by heat, become much larger, and consequently contain much more salt. Water, therefore, must be salter in the seas of hot countries than in those of any other.

Lady Caroline.—Now, Mary, tell me, if you can, why the water of certain wells is seen to fume in winter and not in summer?

Mary.—When a vessel contains water warmer than the air that surrounds it, the fire which exhales from it carries with it the parts of the surface that are opposed to its attack. These small masses, thus detached, rise or extend as much by the impulsion they have received as by the suction of the air, which performs the office of a sponge, and occasions that kind of vapour called fume, which is so much the thicker as the air is colder and fitter for condensation. This is the reason that water fresh drawn from wells in winter, sends up a steam or vapour. In summer this effect does not take place; for when the heat of the atmosphere is greater than that of the well, the fire, instead of exhaling from the water, enters into it, and even could the vapour ascend, the heat which reigns in the air would only fertilize it, and render it insensible to us.

Lady Caroline.—Why, Edward, does the water of lakes and marshes evaporate quicker, and in greater quantity, than that of rivers and other current streams?

Edward.—Because the surface of the waters of the first is longer, and more exposed to the rays of the sun than that of the latter.

Lady Caroline.—What is it, Sophia, that produces the noise and hissing which water generally makes when it begins to boil?

Sophia.—It is caused by the bubbles of air which the particles of fire raise up and impel from the vessel that contains it. When this air is gone out, we only hear a dull kind of noise produced by the parts of water thrown up by the fire, which again fall by their own weight. The noise is more or less loud, as the vessel happens to be made of earth or metal, which last is of course more sonorous.

Lady Caroline.—Whence comes it, Frederic, that when a cook throws into a frying-pan (particularly if it be very hot) fish, or any moist pulse, we hear crackling for some time, and the boiling oil often flies out upon the hands and face of those who happen to be too near it?

Frederic.—Fat substances support a greater degree of heat than water would do, without evaporating. When the particles of this enter into the frying-pan, they are at once trans-

formed into vapours, and suddenly dilating, make the oil by which they are completely enveloped, spout from them.

Lady Caroline.—How, George, is ice caused?

George.—When water does not contain a sufficient quantity of fire, which is the general cause of the fluidity of bodies, its parts, touching each other too closely, lose their respective mobility, attach themselves the one to the other, and form a solid transparent substance, which we call ice: and this passage from one state to another is called congelation.

Lady Caroline.—Why, Kitty, does a glass in which water is frozen, break?

Kitty.—The air that is in the water, as long as it occupies only the pores of this element, that is, the vacuities or similar spaces, does not increase its volume; but as soon as it is changed into sensible globules, when by congelation the parts of the water draw to each other and chase it, this interrupts the continuity of the mass, and makes it become larger. Hence the external surface of the glass swells, becomes convex, and being at last overcome by the water, now converted into ice, it breaks.

Lady Caroline.—The same water, William, when frozen, weighs less than in its fluid state. Give me the reason of this.

William.—The increase of volume gives to

ice that lightness which makes it swim; for one body is lighter than another, when with an equal quantity of matter its volume becomes greater.

Lady Caroline.—It is said, Elizabeth, that melted iron, the instant it loses its liquidity, increases its volume in the same manner as water changed into ice. How can this happen?

Elizabeth.—It is occasioned by an imperfect arrangement of its parts. The moment these are fixed by sudden cold, a very intense heat being necessary to convert this metal to a liquid, and a very small degree of cold sufficient to make it lose that liquidity again, its parts pressed against each other are no longer in a state of fluidity, although they may be still flexible enough to sink, nearly in the same proportion as the fire evaporates, and the motion slackens.

Implements cast from this matter are commonly very expensive, because, instead of quitting the mould like other metals, it unites itself to it as one body.

Lady Caroline.—Water frozen in the barrel of a gun sometimes bursts it; water in the same state raises the pavements of streets, and bursts the tubes of fountains which have not been emptied; nay, it will even burst a vessel of copper, the force necessary to do which, has been

calculated as equal to that which is capable of lifting a weight of 27,720 pounds. Whence proceed these effects, Fanny?

Fanny.—The water increases its volume by freezing, and the air gathering into bubbles, is, without doubt, the immediate cause of this increase of volume; since, without such an interruption, the water would occupy less space; things, however, would be thus, though this air made no effort to extend itself; but it gathers so much the more into these bubbles, as it comes out in greater quantity from the pores where it is naturally lodged. The expansion of volume, therefore, proceeds from the same cause, whatever it may be, that contracts the pores of the water and condenses it: now that which condenses water, and makes a body become hard, is what hardens other bodies when their fluidity is unsupported by some internal cause; and we know by many common instances with what power it acts: for the condensation of water is more quick and powerful, as the cold is more intense. In like manner, ice must be more full of bubbles of air, to have a greater volume, and to be able to make a stronger effort, which agrees perfectly with common experience.

Lady Caroline.—Why, Mary, does water begin to freeze first upon the surface?

Mary.—Because the cold which produces

freezing, comes from the atmosphere; and this cause cannot have its effect at the bottom, without first freezing every thing that is above it.

Lady Caroline.—The middle of a great river, which we call the stream of the water, never freezes. Why is this, Edward?

Edward.—Its motion being irregular, and as it were by leaps, the parts which should attach and unite themselves together, are never two instants at a time on the side of each other, so that the frost has not time to fix and congeal them.

Lady Caroline.—How comes it, Sophia, that the ice of a river that is frozen is not united like that of a lake? And why do we commonly see piles of ice heaped one upon the other?

Sophia.—A great river is never entirely frozen, except when the arches of a bridge or some other obstacle stops the heaps of ice that are borne by its current, and which have thereby opportunity given to unite, and cement as it were to each other.

Lady Caroline.—Pure and clear water, Frederic, freezes in a much shorter time, and becomes much harder than any other. What is the reason of this?

Frederic.—Because, in pure water, there is nothing to make up for the loss of the fire, and to hinder the parts of it from approaching; now

the congelation of the water is only a closer and more intimate union of its parts, occasioned by the absence of the fire, which before kept them distinct from each other, and in a state of mobility.

Salt water freezes with more difficulty, because the parts of the salt oppose the union of those of the water, which, in their turn, hinder the salt from becoming hard, by their tendency to melt it, till it entirely moistens.

The ice of salt water is not every where equally salt, and the middle does not freeze at all, or only takes a very slight consistence; this is owing to the saline particles at last submitting to the force that condenses the water and contracts its pores, entering into the portion that is still liquid, in the same proportion as they are compelled to abandon that which becomes solid. Thus the middle is too much loaded with salt, and freezes less.

Lady Caroline.—What is the cause, George, of the north seas freezing to a considerable depth?

George.—They are exposed to colds of much longer duration, and much more intense than those of other climates; and their waters are also commonly less loaded with salt.

Lady Caroline.—Why, Kitty, is the dirt of the streets, when it begins to freeze, always less hard than ice?

Kitty.—The water is mixed with a great quantity of earth, which makes its congelation much more difficult, by hindering the aqueous particles from joining together.

Lady Caroline.—Why, William, do ice-creams and other delicate preparations by ice, require a much greater degree of cold to freeze them than common water?

William.—Because they are always charged with spirituous sugar, which does the office of salt, and keeps the parts of the water disunited.

When their freezing is only to a degree of simple congelation, some of them are sensibly colder than others, though all may have had the same degree of cold necessary for freezing; because these liquids carry more or less sugar, one than the other, and likewise as they are more or less spirituous.

Lady Caroline.—The water of a standing pool, mixed mith saline liquids, and fat substances, either of animals or vegetables, which corrupt and there freeze, very often represent singular figures resembling the works of art, and even those of nature. What produces this effect, Elizabeth?

Elizabeth.—The parts of the ice are arranged relatively to each other, and to the quantity and order of the foreign bodies that are mixed with the water, and which interrupt or retard conge-

lation: or rather, they are the tracks that the particles of fire have taken, which evaporated in proportion as the water lost its fluidity.

Lady Caroline.—Fruits that freeze in bleak winters, when a thaw takes place, lose their flavour, and very often become rotten. Why so, Mary?

Mary.—Because their juices consist in a great part of water, which freezes and decomposes them: the aqueous particles become small voluminous pieces of ice, which break and burst the little vessels in which they are inclosed.

Lady Caroline.—Why, Fanny, does meat that has been frozen eat peculiarly tender?

Fanny.—Because the particles of ice formed from those of the water, have removed (in dilating by the fire that roasted the meat) those fibres, the union of which constituted the hardness of it.

Lady Caroline.—In countries that are intensely cold, the inhabitants sometimes experience the dreadful calamity of losing their ears and noses. What can be the reason of this, Edward?

Edward.—The humours frozen by the cold swell and distend the organized parts; or rather, their principles remain disunited, when their fluidity comes back to the parts to which it agrees, before the vessels that have been forced

become consolidated. For this reason, they hold them some time in snow before they expose them to a warm air, which gives time for the parts to resume the order which they have lost.

Lady Caroline.—Why, Mary, are the ices of Greenland, and those of almost all the north seas, of a blue colour, approaching a little to a green?

Mary.—This colour may be occasioned in some degree by the condensation and thickness of the air, which, reflecting the solar rays in a certain manner, may produce it: on the other hand, it may proceed from the quality of the bottom of these seas, particles of which may be detached, and mix with their waters, as it happens in many instances.

Lady Caroline.—We encircle with ice, or snow, the ball of a small thermometer, placed in a vessel; then wait till the fluid be fixed to the point of congelation. We now throw upon the ice an ounce or two of any kind of salt. A short time after, the bottom of the vessel is immediately covered with salt water, and the liquor of the thermometer descends below the fixed point we have mentioned. Explain this effect, Frederic.

Frederic.—The cooling of the ice by the mixture of the salts is effected nearly as the

freezing of water. Humidity penetrates the salt, divides it, and enables it to do the same thing in regard to the ice. The two substances mutually penetrate each other as they melt, and the parts of one rapidly running through the pores of the other, drive out for an interval the igneous matter which is still there; and thence arises a great privation of heat in the mixture.

Lady Caroline.—If fire be the general cause of fluidity, and water become ice only when it is destitute of it to a certain point; how can it be that a greater want makes the ice liquid? Tell me, George.

George.—It is not because there is less fire in the ice that it becomes water, but because we substitute for the fire that comes out of it, and which continues to exhale, another substance, that lodges betwixt its parts, continues to exhale, and renders them moveable in proportion to each other. Though fire be the general cause of fluidity, it is not the only one that can give rise to and support this state: it is sufficient that an interposed body should hinder the parts of a substance from joining, and that people should not make use of it as a common link. This body becomes immediately a fluid, whatever degree of cold it may have besides: it is thus that spirits of wine, salt, nitre, &c.

mixed with a sufficient quantity of water, hinders its congelation, and restores to it its fluidity after having lost it; the salt, thoroughly divided by dissolution, produces the same effect, and for the same reason.

THE

EIGHTH DIALOGUE.

ON COLOURS.

Sir Thomas.—I AM, now, my dear children, about to discuss a beautiful and interesting subject, that of Colours. It will inspire you with sublime thoughts, and you will be amazed at the novelty of the knowledge you are about to acquire. The definitions and illustrations which I shall now enter upon, will enable you to answer the questions Lady Caroline may put to you, with as much precision and accuracy as you have exhibited throughout our former dialogues.

Definitions.

Descartes and Malebranche presumed to say, that colours were only modifications of light. Descartes thinks that they are relations of the

straight motion of celestial globules, and of their circular motion round their center. If this circular motion be a great deal more rapid than the other, the colour is *red*; if the circular motion be but a little more rapid, the colour is *yellow*; if the straight motion, on the contrary, be much more rapid, the colour is *blue*: if it be but a little stronger, the colour is *green*.

But according to the hypothesis of Sir Isaac Newton, which ought to be preferred to all the inventions that had preceded and have followed him, Colours are a very particular disposition of luminous rays, adapted to give the perceptions of *red* or *yellow*, &c.

Every ray takes the name of the colour that it bears; not that it is really coloured, but that it occasions one appearance rather than another.

According to the same author, one species of rays produces in the organs, vibrations of a certain magnitude, which raise in the mind a sensation of a certain colour; in the same manner, nearly, as the vibrations of a certain magnitude in the air give rise to a sensation of a certain sound. For instance, the rays of one species that produce the shortest vibrations, shew the *violet* colour; the rays of another species that produce vibrations the most expansive,

give the *red.* The first are the causes of short vibrations, because they are compounded of the smallest corpuscula. The last of these, having less force than the others, make less impression. Thus, the *violet* that they give rise to, is the most gloomy and feeble of colours. The second occasions the most extended vibrations, because they have larger corpuscula, which having more strength than the others, make a stronger impression. The difference of size in the corpuscula of other rays makes the difference of other colours. Hence red, orange, yellow rays, &c.

Newton reckons seven principal rays or primitive colours: the first is *red,* or of the colour of fire; the second *orange;* the third *yellow;* the fourth *green;* the fifth *blue;* the sixth *purple* or *indigo;* the seventh *violet.*

This may be easily illustrated by the following experiment:

Let the sun shine into a dark room through a small aperture as at *e, e* (plate iv, fig. 5,) in a window shutter, and place a triangular prism B C in the beam of rays A, in such a manner that the beam may fall obliquely on one of the sides *a* b C of the prism. The rays will then suffer different refractions by passing through the prism; so that instead of going all out of it on the side *d c* C, in one direction, they will

pass on in the different directions represented by the lines *f, g, h, i, k, l, m, n*; and falling upon white linen or paper placed as at *p, q*, to receive them, they will paint upon it a series of most beautiful colours, in the following order:

Those rays which are least refracted by the prism, and therefore go on between the lines *n* and *m*, are of a very bright red at *n*, degenerating gradually into orange, as they approach the line *m*. They next appear of a fine orange colour at *m*, and from thence change into a yellow colour toward *l*. At *l* they are of a beautiful yellow, which inclines toward green as they approach *k*. At *k* they appear a pure green, but from thence toward *i*, they gradually change to blue. At *i*, they are of a perfect blue, inclining to indigo colour as they approach *h*. At *h* they assume the perfect colour of indigo, which changes gradually to violet, the nearer they advance to *g*. And at *g*, they will be of a bright violet colour, which will change to a red as they approach *f*, where the coloured image terminates.

You must observe, my children, that the quantity of rays in these colours is not the same; for if the oblong image *p, q* were divided into 360 equal parts, the red space R would occupy 45 of these parts; the orange O, 27; the yellow Y, 48; the green G, 60; the

blue B, 60; the indigo I, 40; and the violet V, 80.

If all these colours be re-united, they will make a pure white; as may be proved thus:—Take away the white linen or paper on which the colours *p q* fell, and place a large convex glass D in the rays *f*, *g*, *h* and *i*, which will refract them in such a manner, as to make them blend with and cross each other at W, where if a white paper be placed to receive them, they will excite the idea of a lively white; but if placed at a greater distance from the glass as at *r*, *s*, the different colours will re-appear, in an inverted order occasioned by the rays crossing at W.

From the mixture of these seven rays arise all the colours of nature, and the whole of them re-united and reflected together from the surface of an object, produce whiteness; and we only call them *red*, *green*, &c. because the rays make such impressions upon the retina, whether it be because the globules of the rays are of different sizes, or that they may have a different motion. And not only reflecting surfaces have their pores filled with light, to reflect that which falls from above; this light in coloured surfaces is of such or such a species, and by that means capable of receiving and restoring to similar globules the motion that is most

proper to them. Thus cochineal dyes red, yet not of itself, but because its particles, divided and lodged in the pores of wool, are like so many sponges imbrued with red light, adapted to re-act against a similar light, and upon which the rays of a different nature are deadened and extinguished by the want of an effectual re-action.

Let us conceive transparent bodies that have colours, not as simple sieves, but as little beams of which the meshes contain some particular species of light, adapted to receive and to transmit, beyond the motion communicated to it, by rays of one and the same nature. The pores of red wine contain a series of globules, which, struck by a compound light, only receive and transmit the motion that belongs to the rays of that colour.

I shall now resign to Lady Caroline the task of illustrating what I have been saying, and hope that these preliminary observations have already prepared your minds for the explanation of whatever her Ladyship may propose.

Lady Caroline.—There are found, George, in certain places, stones, generally of the size of a hen's egg, of an irregular round figure, their colour grey, and in their nature something like talc (a transparent mineral, of which a curious white-wash is generally made). This stone, or

any other that may be substituted in its place, having been calcined in a coal fire, and kept in a box internally covered with cotton or flannel, we expose to the free air and open day during a few minutes, but place it in the shade: we afterwards take it out of the box, to be seen in a darkened room; and that the experiment may succeed better, it is proper that those who are to look at it shut their eyes for a few minutes before, or stay in the room till it is shewn. The stone then will appear luminous, like a piece of iron reddened by fire, and beginning to extinguish. This light lasts a few minutes, but becomes gradually more feeble, after which it entirely disappears. Account for this.

George.—The odour exhaled by this stone (which, I recollect, Sir Thomas told us was a native of Bologna in Italy) after having passed the fire, gives us to understand that its natural sulphureous particles have been disengaged from its earthy parts. These subtilized particles of sulphur contain like other particles of fire, but with this difference, that being very much disposed to obey the expansive force of this element, their inflammation begins in an instant. The most feeble light of the day is sufficient to give light to this stone, which placed in the dark produces these effects.

Lady Caroline.—Why, Kitty, do bodies appear to us under several different colours?

Kitty.—The figure of their pores, the texture, the consistency, and the inclination of their parts, reflect more rays of a certain species, while they transmit the greater part of the others; that is, they absorb them.

The particles of which the surfaces of bodies consist, may be conceived as blades of a very minute thinness, of different natures; and as the rays are themselves entirely dissimilar, they do not find in all these minute blades upon which they may fall, the same relations and dispositions. One blade, for instance, that will receive and break the yellow in its pores, will totally force the green. Certain bodies appear to us red, because they reflect and send back to our eyes a great quantity of red rays. Gold reflects yellow rays, while other rays pass over them; for if we place betwixt the light and the eye, a very minute blade of gold, the light traverses it, and appears blue or green.

A surface of a body which in a certain inclination would have admitted and bent the violet, being otherwise inclined, refuses its passage, and wholly reflects it.

A pigeon, or a pheasant cannot make the least motion with its head without exhibiting, sometimes little surfaces adapted to reflect cer-

tain rays; at other times, other surfaces, calculated to reflect quite different rays from the first. In the mixture of some liquids, there are formed particles or layers that reflect many more rays of certain species than of others, which run through the mixture, or which are there absorbed; hence the colours which we see suddenly rising. It is easy to perceive that all these changes may be infinitely diversified.

The small irresistible parts of the surfaces of all bodies may be considered as so many fine sieves, which, if I may be allowed the expression, sift the light. The rays that may be received and admitted by the pores of one sieve, may be rejected by another. The white is a very fine sieve, which allows no ray to pass; the black is the largest sieve, and through it every ray flows. Hence it happens, that white woven substances are more cool, and less calculated to receive heat. It is upon this account also, that a sheet of white paper pinned to the hat of a traveller, saves him from a too intense heat, by sending it off into the air; and for the very same reason, black clothes and all black bodies receive a vast deal of heat, and sometimes are upon the point of being burned.

Colours are then essentially different in us, upon us, and in light, as well as upon all coloured bodies. In us, they are very different

sentiments, by which we are intimately affected in the appreciation of the appearance of objects. In light, they are so many darts, simple and distinguished from each other. Upon coloured bodies there is a very certain foundation to say of one, that it is red, and of another, that it is blue; since particles that reflect one of these colours are, by the inequality of their structure, their density, their delicacy, their arrangement, and their inclination, very different from the particles which constitute a surface of another colour.

Black is not properly a colour: it is a privation of reflected light; and the less the reflection is, the greater is the blackness. Some opaque or dark bodies send back but a very small quantity of light, the remainder of which becomes extinct in these bodies by being dispersed on all sides through contrary reflections and refractions; and hence, it undoubtedly proceeds, that a black substance is more rapidly heated than any other.

Lady Caroline.—A ray of the sun obliquely falling upon the *surface* of a tumbler of water, placed upon the border of a table, displays the prismatic colours at the distance of some feet from it: this does not usually happen, except the light, which traverses the glass, be extended

a little farther after its emersion. To what, William, may this be attributed?

William.—The mass of water which the solar ray traverses, is in this case a true prism, of which the refracted angle is toward the rim of the glass; it must therefore produce similar effects to those of a solid piece of glass, with the same form as the water and the tumbler; but as the different degrees of refrangibility of the rays do not remove them from each other, but under very acute angles, it is only at a considerable distance from the refractive body, that they are sufficiently unmixed to appear with their own colours; nearer the glass, there can be at the most but the border of the emergent light, coloured, and that in a faint degree.

Lady Caroline.—Diamonds, especially those of the finest water, held in a ray of the sun, produce by their angular cut, a vast number of small beautifully coloured figures. How does this happen, Elizabeth?

Elizabeth.—From their facets, which form so many small prisms. The incident light is divided into many small shootings, which are still subdivided upon the facets, differently inclined from the bottom, and which reflecting from this, fail not to be decomposed by coming out, if they have not been so by entering. Co-

lours are more vivid in the diamond than in glass, because they are better separated; the first being more refractive, and its transparency more perfect. The light of a wax taper produces the same effect, though with less splendour than that of the sun. It is for this reason that night assemblies are so favourable to those parts of dress that are ornamented with diamonds: shootings of direct light, multiplied in a place where the light is less powerful than by day, render the effects of which I am speaking more sensible and more numerous.

Lady Caroline.—Paper dyed blue becomes at first a fine red, and some time after turns pale, when it has been washed over with aqua-fortis, weakened by a little common water: nearly the same thing is observed when we apply to it any other acid, as the juice of citron, vinegar, spirits of vitriol, the simple dissolution of nitre, &c. How does this happen, Henry?

Henry.—The particles that give the colour to the surface of the paper being freed by the action of the acid, change their size and figure, and thereby become fit to reflect red, rather than blue or violet rays; and as this action remains a certain time before it has its full effect, the red, which appears at first very deep and vivid, runs through many successive shadowings to a colour more weak and pale.

Lady Caroline.—At the close of day, the shadows of bodies produced upon a white wall are of a blue colour. Give me the reason of this, Fanny.

Fanny.—The shadows of bodies proceeding from the red hue of the setting sun, which is near the horizon, will always be of a celestial blue; because the surfaces of all opaque bodies take the colour of the body which enlightens it; therefore the whiteness of the wall being entirely destitute of colour, it takes the hue of its object, that is, the sun and the heavens; because the sun towards evening is of a colour approaching to red, as the heavens to the blue; and the places where the shadows are, not being seen by the sun (since no luminous body can see the shadow of the object it enlightens), as the places of this wall where the sun does not shine are seen by the heavens, the shadow reflected by them upon the white wall will be of an azure colour; and the spot of this shadow being enlightened by the setting sun, inclining to red, will likewise partake of this red colour; that is, the white wall takes the hue in a visible manner of the celestial blue light of the heavens, and this colour appears only in the place of the shadow, because the other parts of the wall are illuminated by a stronger light, which hinders the blue from appearing. This will take place,

though the shadow be but faint, and on this we may rely when the sun is not too much above his descent, or better if he be descended.

Lady Caroline.—To what cause, Mary, can we attribute the beautiful red with which lobsters, crabs, and a variety of other shell-fish, are tinged when boiled?

Mary.—It may be attributed to some change of their superficial contexture, which becomes fit to reflect only the red rays; a change so delicate and so imperceptible, as not to be discoverable by the most piercing eye, assisted by the best microscope.

Lady Caroline.—I take this phial of thin glass, which is exceedingly transparent, and the figure of which is cylindric, about an inch in diameter, and seven or eight inches in length: I fill it nearly one half with clear water, and pour upon it as much spirit of terebinth; after which, without moving it from the place it stands on, I cork it as closely as I am able.

You now observe, that so long as I do not agitate the phial, the two liquors remain one above the other, and each of them preserves all its transparency: but on shaking the bottle for a few moments, the two liquors mix in such a way that the water is interrupted by an infinite number of small globules of terebinth of a

dull and thiek white. How is this oeeasioned, Frederic ?

Frederic.—The spirit of terebinth, being lighter than the water, remained on the top when your Ladysdip gently poured it into the bottle; and the two liquors, thus separated, preserve the qualities that are peeuliar to them, and consequently their natural transparency. But when, by the agitation of the bottle, the least dense of the two divides into small globules, the continuity of the water is interrupted, and a mixture is formed, of which the parts are heterogeneous as to the density; then the light is lost by the irregular reflections and refractions which it undergoes in this mass; and the rest, repelled and making its way baek again, shews the mixture under a white appearanee.

Lady Caroline.—Water beaten in its fall by the wheel of a mill, the white of an egg whipped, and in general all mucilaginous substances, are opaque and white. Give me the reason of this, Sophia.

Sophia.—This happens beeause the air, which introduces itself into them in small globules, and is mixed with matters much more dense than itself, composes with them masses, the parts of which are very different in density.

Lady Caroline.—Glass, ground, cracked, or

unpolished, which has lost its transparency, resumes it, like an infinite number of other bodies, by being only moistened with water. Oiled paper also is very often substituted for the pane of a window. Why so, George?

George.—Because we supply for the air which fills the pores and inequalities of these bodies, a liquid, of which the density approaches nearly to theirs.

It must be observed, that the glass is so much the more transparent, as it is more thin and polished, because its pores are by this so much the less interrupted, and less closed; and consequently give easier passage to the rays of light.

It is so much the less transparent as it is thicker; because then its pores being more crooked, obstructed, and stopped with solid particles, the rays pass with greater difficulty.

Water, when frozen, is very transparent, while oil in this state almost wholly loses its transparency; because the parts of the water in approaching are so arranged, the one next the other, in parallel lines, at the moment when they freeze, that they always preserve a great number of pores, free, and disposed in every direction; whereas the parts of the oil are intermixed in such a manner, that the passages of

the light become tortuous or winding, and inaccessible to the greatest part of the rays.

Lady Caroline.—In frosty weather, the glasses of a carriage in which persons are seated, become very soon dull and obscured, so that objects on the outside cannot be distinguished. What can be the cause of this, William?

William.—It is occasioned by the transpiration of the body, which attaches in small drops to the surface of the glass. These particles of water, with the partitions of air, separate; and compose a layer of matter very heterogeneous as to density, and on that account very little adapted to allow the light to pass in a right line. What proves that the glass does not lose its transparency is, that if the small drops be re-united with the hand, or a handkerchief be slightly passed over them, the glass immediately resumes its former transparency: it is even a means of preventing its becoming any more so obscured, for the humidity that arises afterwards, only unites to that which is extended, and takes no more the form of drops.

Lady Caroline.—How, Fanny, is any black object perceptible, since no kind of light is reflected from bodies of this cast.

Fanny.—When we look upon a black body, it is not that body that we see, but the enlightened or luminous surfaces that encompass it,

and which serve as a field: the light that they send, makes impression upon the whole of the sight, except at the place which corresponds to the body that we have in view. This place of the organ which does not receive the light, is circumscribed and terminated according to the figure of the black body, which is the cause of this privation; and by this we are enabled to judge of the magnitude, form, situation, and nature of it. When we read a book, it is not the letters of ink that make impression upon our eyes, but the white of the paper that is betwixt them, since it is from this that the light comes: we distinguish them only by the defects of sensation which they occasion.

Black substances do not appear to us, as stains or shadows: a man dressed in black, and an animal of this cast, look very different from shadows. We distinguish all the parts with their reliefs: it is that these objects are not entirely black, as we may imagine them; the parts the most prominent, and the most exposed to full day, detach themselves from the others by shadings more or less clear, and the reflection of the light, which shews the mouldings, contours, and projections of them. This is so true, that a painter who undertakes to represent them cannot effect it, but by employing white and other colours capable of reflecting

the light; and if these bodies are not enlightened on the side by which we view them, they appear to us like real shades.

Lady Caroline.—Why, Edward, do astronomers burn or smoke the glasses, through which they look at the sun?

Edward.—Because all black bodies, as well solid as liquid, being generally best adapted to intercept the light, the eye is not overpowered by a too great resplendence of rays. The sun then appears of a yellowish red, because of all the species of light that emanate from him, those of red and yellow are the most strong, piercing through substances and degrees of opacity in which the other colours stop and become extinct.

Lady Caroline.—When we look at a glass of red wine in which water is mixed, we distinguish neither the parts of the water, nor the solid parts of the glass. The sensation it gives rise to within us, is only that we see the simple wine without any mixture or interruption. How happens this, Sophia?

Sophia.—The impression that comes from the red wine is stronger than that which proceeds either from the glass or the water; and this spreading upon the retina renders both the latter insensible.

Thus a green meadow scattered over with

white flowers, when viewed from a great distance, appears entirely white.

Lady Caroline.—How, Frederic, is the rainbow produced ?

Frederic.—We call by that name the arch that appears when a spectator has his back turned towards the sun. It is seen in a dull thick part of the atmosphere, while it rains, betwixt this and the sun. It often happens that we see at the same time two of them parallel to each other. The colours of the uppermost are more faint, and inverted, in relation to those of the lower, and are the same as those seen in the rays of the sun passing through a prism. We may observe, in general, that in the lowermost bow, the solar rays make a double refraction, first at the entrance into the drops of rain falling from the atmosphere, and again when they issue from them, besides one reflection which the ray makes in the interior of the same drops. In the upper bow, there is not only a double refraction, but, besides, a double reflection. It is not therefore surprising, that, the rays in this bow being more faint, the colours should likewise be less vivid. In the superior arch, the rays entering into the drops of water by their inferior parts, proceed to the eye from their upper surface; and in the other arch, they penetrate at first the superior parts, and then ad-

vance towards us by their inferior part. Hence, it necessarily follows, that the inverted order must take place.

Lady Caroline.—I mix in this cup the tincture of sunflower with aquafortis and oil of tartar; the mixture gives a violet colour. Why so, Mary?

Mary.—The mixture is violet when it reflects more rays of this colour than any other: it is blue when it sends forth more of the blue. On the same principle there arises a fine blue from the mixture of alum with the juice of corn flags.

Lady Caroline.—Again, Mary, I put into this cup a little water and oil of tartar upon the syrup of violets, which mixture immediately produces a beautiful green. In what manner is this effected?

Mary.—This mixture, absorbing the other rays of light, reflects the green only.

Lady Caroline.—The spirit of vitriol in a tincture of the pomegranate gives a colour bordering upon orange. How happens this, Kitty?

Kitty.—Because this mixture reflects back only the orange rays, absorbing the others.

THE

NINTH DIALOGUE.

ON VISION.

Sir Thomas.—WE now proceed, my children, to the science of light in general, and I flatter myself that you will attend seriously to my preliminary observations, as they will enable you to answer Lady Caroline's questions with ease and propriety.

1st. The science of optics demonstrates the laws according to which the rays of light depart from a radius, and terminate at the eye.

The science of catoptrics teaches us the laws that the rays of light follow, which are reflected by a body, and of which the image is conveyed to the sight.

Dioptrics is that science which treats of the laws according to which the luminous rays pass through mediums more or less dense, more or less rarefied, and changed or broken by them.

Light is an infinitely subtile matter which strikes upon our eyes; which paints objects to them over which it is reflected; and of which the impression is followed in us by another which affects the mind, and acquaints us with

the presence, the arrangement, the figure, the situation, and the distance of objects. Visible objects, as the eyes, by which they should be perceived, are always plunged in a fluid that extends without interruption from one to the other: this intermediate matter is susceptible of a species of motion that cannot be felt but in the bottom of the eye, in the same manner as it can only be excited by blazing bodies, or those similar to them. As soon as it is agitated in this manner, the organ, placed wherever it may happen to be in the sphere of activity, fails not to be affected by it; and on this occasion the mind perceives and judges at a certain distance, and in the direction of the motion by which impression has been made, the object that is the cause of it. The matter of light is the same as that of fire, because it enlightens and burns like fire; the same element produces these two effects, and if we see one without the other, it is that both do not depend upon the same circumstances, although they have one and the same principle.

Those who pretend that the sun continually sends the light to us, do not solidly answer an insurmountable objection: for if the sun send light, it ought incessantly to lose its substance, and consequently become smaller and less splendid; this, however, does not take place.

Will the objectors say, that comets are thrown into the sun to serve him as aliment? Or that the loss sustained by the sun is always repaired by the same matter, which returns to it again? These answers offer nothing solid, and it appears to me that we ought to prefer the system in which it is said that the matter of light is spread throughout the world, and in order to shine, it waits only for a certain motion which the sun gives to it.

For a candle to enlighten three miles round, it is not necessary that it send the luminous matter every where. It is sufficient that it impress a certain motion to the subtile matter expanded in that place. If that be easily comprehended, why should we not say the same thing of the sun? May we not consider it as the candle, and of course say, that this luminous star, impressing a certain motion to the matter of light of which the universe is full, occasions it to enlighten us?

We may consider the particles of a luminous ray that is extended from a star to our eye, as so many little balls or small elastic clusters, and very contiguous; whence it happens, that the action of the luminous body in all the length of the ray which ought to transmit it, is not instantaneous but to our senses, and in the case of a very short distance: but this transmission,

however rapid, and imperceptible it may be, requires a real succession of instants, of which the sum will become very considerable, if the way that the light should run through be very long.

We call *divergent rays,* two rays, which, departing from the same point, are always removed one from the other in proportion as they advance. We give the name of *convergent rays* to those which coming from different points of the same object, approach each other in proportion as they continue their way. By *optic* or *visual angles,* we understand the angles formed by the rays that dart from the extremities of the object, and cross each other in the prunella.

The angle of incidence, is that which is contained between a ray of light and a perpendicular to the refracting surface. *The angle of refraction* is an angle contained between the same perpendicular, and the same ray after refraction. Thus let L B M, plate iv, fig. 6, be the refracting surface of a medium of water, and A B C a perpendicular to that surface : let D B be a ray of light passing out of the air into the water at B, and therein refracted in the line B H ; the angle A B D is the angle of incidence, of which D F is the sine ; and the angle K B H is the angle of refraction whose sine is K I.

When the refracting medium is water, the sine of the angle of incidence, is to that of the angle of refraction, as 4 to 3. In order to prove this, draw the circle D A E C on a square board, and cross it at right angles with the straight lines A B C, and L B M; then from the intersection A set off the equal arcs A D, and A H, and draw the right line D F E. Then taking F *a*, which is 3 quarters of the length F E from the point *a*, draw *a* I parallel to A B K, and join K I parallel to B M: so K I will be equal to 3 quarters of D F or F E. Then fix the board upright on the pedestal O, stick 3 pins perpendicularly at the points D, B, and I. Then set the board upright in the vessel V U T R S, and fill the vessel with water to the line L B M. When the water has settled, look along the line D B, so as you may see the head of the pin B over that of the pin D, and the pin I will appear in the same right line produced to G, for its head will be seen just over that of the pin at B: this shews that the ray I B coming from the pin at I is so refracted at B, as to proceed thence in the line B D to the eye of an observer, as it would from any point in the right line D B G if the vessel were emptied of the water: it also shews that K I the sine of refraction in water, is to D F, the sine of incidence in air, as 3 to 4.

The *radiant point* is that whence depart many divergent rays. *The focus,* or *point of concourse,* is that where the convergent rays are gathered together.

The rule of the diminution of light is in an inverse ratio of the square of the distance, and the rule of its increase is likewise in an inverse proportion of the square of the distance.

I say, in the first place, that the ratio of the decreasing of the force of light is in the inverse ratio of the square of the distance. I will here instruct you, my children, how to understand this expression. If after having measured the distance from a hole of a window in a darkened chamber to the wall, you present to the opening a spiral small tube of wax of any colour, lit on its stand, you will perceive that the light received at one foot from the hole upon a piece of pasteboard, is very strong; that at two feet from the hole it diminishes, not by the half, but by the quadruple; multiplying two by two, you have four for the square of the distance; that at four feet, the pasteboard will be sixteen times less lightened than if it were at one foot, sixteen being the square of four; so that at five or six feet, the light is no more than the twenty-fifth or the thirtieth part of what it was when it first issued from the luminous body.

I say, in the second place, that the ratio of the increase of the strength of light, is an inverse ratio of the square of the distance. When, for instance, the rays of light, instead of straying, converge and tend towards the same point, departing from the base of a cone to join in its apex or summit, they fortify each other in proportion as they approach the common point, where they will re-unite; and this convergent light continues to increase as the square of the distance diminishes; so that it is four, nine, sixteen, or twenty-five times more strong, or the distance in respect of the same point is found, four, nine, sixteeen, or twenty-five less than it was before.

If parallel rays in their incidence be reflected by a plane mirror, they constantly remain parallel as they were before.

If divergent rays in their incidence be reflected by a plane mirror, their divergency does not change.

If convergent rays in their incidence are reflected by a plane mirror, the rays preserve the same degree of convergency.

If the convergent rays in their incidence be reflected by a convex mirror, their convergency diminishes.

If the rays which fall parallel together, are

reflected by a convex mirror, they become divergent by the reflection.

If divergent rays are reflected by a convex mirror, they become more divergent.

If parallel rays are together reflected by a concave mirror, they become more converging.

If convergent rays are together reflected by a concave mirror, they become more converging than before they had touched the mirror.

If diverging rays in their incidence be reflected, they become less diverging.

Refraction of light is a deviation which its rays undergo in certain circumstances, by passing from one medium into another. Light is refracted in these two re-united emergencies; that is, when it passes from one medium into another, more or less dense, and that its direction is oblique to the plane which separates the two media: I mean, that (with whatsoever direction) the ray of light would not suffer any refraction; if issuing from the air, for instance, it should enter into a diaphanous or transparent matter, which should be neither less nor more penetrable for it than this fluid; and that even where there is a difference of penetrability betwixt the two media, the ray of light would traverse through them into a right line, if, when it goes out of one, it falls perpendicularly upon the surface of the other.

The true cause of refraction is this; the strength of the solar ray from a rarefied medium into a more dense one, is broken at the moment of its entrance into a denser medium, and flies off from the perpendicular line which falls through this last.

We give the name of *point* of *incidence* or of *refraction* to the point or the ray of incidence, which with the broken ray makes the angle. The rays of light are always refracted when they obliquely pass from one medium into another, that is, of a greater density or of a different nature.

When light is refracted by passing from a rarer medium into one more dense, the angle of refraction is smaller than the angle of incidence, and reciprocal to the former.

This law, however, admits of some exceptions: fat or sulphureous matters for the most part, which are transparent, refract the light more strongly than a person might expect, if he did not attend to their density. There are in them two causes of refraction, one belongs to their density, the other depends on their particular nature: this last may amply supply that which the other cannot do, or produce a just compensation; whence it may happen that light passing from a rarefied medium into a more dense one, may make its angles of refraction

much larger than that of its incidence, or it may make them both equal, that is, that the ray is not refracted at all. We might even cite examples of these cases, which are contrary to the general law; but as this law is true in the common course of things, and particularly as to bodies in which it is the most necessary to follow the motions of light, we should always consider the general proposition as a principle of dioptrics.

Although the refraction of light become more or less great, either by the degree of obliquity of the incident ray, or by the nature of the refractive medium, the sines of the two angles of refraction and of incidence remain always in constant proportion.

Neither refraction nor reflection can sensibly alter the activity of light; since a refracted ray forced to return on itself, resumes, as it issues from the refracted medium, the very direction that it had in its incidence.

The refracted and incident rays are always found in the same plane, which is perpendicular to the surface of the refracted medium.

If parallel rays in their incidence fly through a rarefied medium into one more dense, which may be terminated by a plane surface, the refracted rays remain parallel.

If converging rays in their incidence traverse

a medium more dense than air, and terminated by two plane parallel surfaces, the convergency of these rays diminishes when they enter it, and increases when they depart from it.

If diverging rays in their incidence enter into a medium more dense or more rarefied, bounded by plane and parallel surfaces, they lose a part of their divergency, and resume it when they leave it.

If parallel rays pass from a rarefied medium into one more dense, bounded by a convex surface, they become converging.

If the converging rays which flow from a rarefied medium, are received in one more dense, and bounded by a convex surface, they become more and more converging than they naturally are, or remain such as they were by passing through the air in this refractive medium.

If diverging rays pass from a rarefied medium into a denser, bounded by a convex surface, they lose a part of their divergency, and may become parallel, or even converging.

If parallel rays pass from a rarefied medium into one more dense, terminated by a concave surface, they diverge.

If converging rays pass from a rarefied medium into a dense one, bounded by a concave surface, they necessarily become less converg-

ing than they were, and may become parallel or even diverging.

If diverging rays issue from a rarefied medium to enter into a denser one, terminated by a concave circle, they can undergo no change; but they may become more or less diverging, than they naturally are.

Surfaces perfectly reflecting, such as mirrors which send back every species of light, separately or altogether, contain in their pores, like limpid bodies, as glass, water, &c. globules of every order, and in proportion similar to that which nature has observed in the composition of solar light: whence it happens that these bodies are always ready to repel or transmit the action of the homogeneous rays, separated or reunited.

White surfaces, and bodies that have but an imperfect and colourless transparency, differ from these last only in this, that the incident light is there reflected, or passes through, with loss and irregularity, either from the want of order in the pores, or by the figure, the size, or the arrangement being unfavourable to the parts of these bodies.

What we call dusky, obscure, and black, is only a privation of a greater or less light transmitted or reflected: for the same reason that

enlightened bodies, which appear such to us, absorb or extinguish the action; and this effect ought to be attributed to the light that fills the pores which is too much engaged among the parts of the matter that contains it, and by this means is incapable of receiving and communicating a great part of the shock inflicted by the incident rays.

Since gold, which is of all known matter the most dense, becomes transparent when it is made infinitely thin by gold-beaters to a certain point, it is reasonable to think that there is not a body which in its nature is of absolute opacity; and as we see bodies the most diaphanous, transmit so much the less light as their thickness increases, we may surely say that there is no medium perfectly transparent, and which may not become opaque: I only allude however to relative and comparative opacity and transparency, in order to show how one body is more opaque or more diaphanous than other.

You see, my children, that I have entered largely into the subject of light; yet I have dwelt on nothing but what is essentially necessary; and it will require all your attention to understand and retain the different principles that I have been laying down. I shall now, having given you the clearest insight into the

subject that my reasoning powers are capable of, resign you to Lady Caroline.

Lady Caroline.—Why, George, do certain insects, as glow-worms, shine in country places during night?

George.—The light sent forth by these animals, proceeds from a fluid matter, which they have in their bowels, and which will shine some minutes even after it is pressed from the part which contains it. It seems, however, that it is in the power of the animal to allow it to shine, or to extinguish it at pleasure; for it does not always shine with the same brightness, and sometimes it is not seen at all. This renders it probable, that it is a species of phosphorus which makes a part of the animal. This composition is a matter, in which the element of fire is but very slightly engaged, so that it is easily animated to the point that is necessary for lighting a matter, very similar in its nature, residing in the air.

Lady Caroline.—A multitude of people see all at once, whatever single object presents itself to their eyes; thus a numerous troop of soldiers obey a signal given by one person; a star may be perceived at the same instant by a great number of the inhabitants of the earth, &c. How are these things to be accounted for, Kitty?

Kitty.—I conceive, that around a luminous body standing by itself, there is not one place so large as the prunella of the eye of the smallest animal, that may not receive the basis of a pyramid of rays animated or sent back by that object; it is therefore painted in the eye, and the mind attending to this representation perceives the object.

Lady Caroline.—A fowler aims his gun in the direction of the partridge; an engineer, to make straight any way or ditch of a rampart, plants small white sticks, of which the extremities are found ranged in the visual ray; a geometrician judges an object in the line of direction of the sights or glasses of his instrument. Why so, William?

William.—Because the pyramids of light which come from the radiant point to the eye, and are called rays, are perfectly right in a homogeneous medium. This is received as an axiom, and it is very necessary that it should be so; for if we were not sure that the ray which goes from the object to the eye were perfectly straight in the whole of its length, we could not conclude and determine the position of this object by the part of the visual ray which would have followed the instrument in reaching the eye; and in that case we should be most unpleasantly embarrassed.

Lady Caroline.—The crew of a vessel, in coming from the main ocean towards land, perceive the steeples and roads of a town before they see the stones of edifices, or any of the lower parts of them; and those who are already in port, first discern the arrival of a vessel by the heights of the masts and sails, before they discover the body of it. How does this happen, Elizabeth?

Elizabeth.—It proceeds from the convexity of the sea, which follows that of the globe of the earth, of which it makes a part; but this happens thus only through the curve of the surface of the water, which interrupts the visual ray of the spectator, who seeks for the lower parts of the object.

Lady Caroline.—What is a shadow, Henry?

Henry.—Properly speaking, it is nothing more than a light extinguished by the interposition of an opaque body: it should consequently occupy all the space that would be enlightened by this portion of light, if it had the motion which it can no longer receive.

Thus a very small obstacle produces much shade when it is very near the luminous body, and makes less in proportion as it is further removed from it: the proportion is such, that the number of the intercepted rays diminishes as the square of the distance augments; that is, when

the obstacle is at a double, triple, or quadruple distance, it intercepts four, nine, or sixteen times less light than when it was at the first dis tance.

Lady Caroline.—Why, Fanny, by looking too far do we often miss the object of our search?

Fanny.—The visual rays, occasioned by their divergency, are too rarefied for what enters into the prunella to be sufficiently felt. But this degree of distance in which the sight fails, varies according to the state of the eye, the nature or qualities of the object, and the intensity of the light which renders the object visible.

Lady Caroline.—Owls, cats, and other animals who prowl by night, perceive objects in the dark. How does this happen, Mary?

Mary.—These animals have very open eyes; and, as in general, they only see by very faint and rarefied rays of light, nature has given them the means of receiving a greater number of them; and, without doubt, has joined to this advantage, that of a very sensible organ: for we may remark, that great light hurts the eyes of these animals, and that when they are exposed to it, they take care to draw in the prunella, which seems to have a particular organization for that purpose.

Lady Caroline.—Although the eye change

place, it always perceives the same object before which it is situated. How, Edward, does this happen?

Edward.—The eye which is performing its function, becomes the common basis of an infinite number of pyramids of light, which have their apices, or ends, in the radiant points of the visible body; and although the eye changes its place, it perceives always the same object, not by those rays by which it was first struck, but by others altogether similar; since every point of the surface which it contemplates, animates a whole hemisphere by these diverging rays, of which each luminous pyramid is only a very small portion.

Lady Caroline.—In a room close shut, and where light enters only by an aperture in the window-shutter or the door, we see on the ceiling and on the wall, in an inverse order, the figures and motions of objects passing without. What reason can you assign for this, Sophia?

Sophia.—All the clusters of light tend from the different points of the object to the eye, and cross each other in the prunella.

It is a known fact, that every enlightened object placed before the eye, is painted at the bottom of this organ; and that its image there takes a situation exactly opposite to that which it really has. A man who stands before it, is there

represented with his head downwards, and his right-hand where his left should be. We may be convinced of this by a very curious experiment, but which requires a little dexterity in order to perform it with success. We must shut up the doors and windows of a room, by which it will be rendered totally dark; then bore in one of the shutters a round hole of a diameter equal to six-twelfths of that of the eye, and in that hole place the eye of an ox newly killed and from which all the teguments have been taken, excepting the last, which immediately touches the vitreous humour. If this preparation be well made, and we have taken care not to change the natural form of the eye by pressing it, those who are in the room will see at the bottom of the eye, in an inverted position, the objects without, with all their motions and natural colours, and with a peculiarly bright appearance.

Lady Caroline.—How is it, George, that on a lake we are less certain of striking the birds at which we aim a gun, than in any other place?

George.—It is not, as is commonly supposed, that the ball sensibly preserves there less velocity than upon the open plain; but that, not being able to aim well at a distance, through the

deception of the water, we shoot too far without being aware of it.

Lady Caroline.—When we enter a long avenue, it appears to be lower and more narrow at the other extremity, although the trees with which it is formed be every where equally high, and the rows exactly parallel. What is the cause of this, Kitty?

Kitty.—It is occasioned by the rays that come to the eye from the farthest of the trees, taken two by two, and which form angles more acute than those that are situated nearer. The same thing may be observed of those rays which proceed from the root of each of these trees and their summits.

Lady Caroline.—We entirely lose sight of, or see but very confusedly, an object of which the likeness is diminished beyond a certain point. Give me the reason of this, William.

William.—Because then the different parts are no longer painted upon the places of the organ, that are separated sufficiently from each other: it is said that the human sight ceases to be distinct when the optic angles come under one minute of a degree.

Lady Caroline—Why, Elizabeth, do the sun and moon, which are really globular, offer to

our eyes only circular and luminous planes, as if they were simple disks?

Elizabeth.—Because all the lines which constitute their convex surface, are presented to us as straight lines.

Lady Caroline.—If we look at a man who is about a hundred paces from us; according to the rules of the visual angles, he should appear about as small again as if we saw him at fifty paces; for his image in the bottom of the eye diminishes in this proportion, notwithstanding he appears to us in both these cases nearly of the same magnitude. What is the reason of this, Henry?

Henry.—By being thoroughly assured that a full grown man, has, in general, not less than five feet in height; and perceiving in his air and exterior every thing that constitutes man's estate, we implicitly admit the idea to this, without paying attention to any thing that might break down the limits of sensation, and overpower the judgment.

Lady Caroline.—What is the reason, Fanny, that the sun and full moon appear much larger in the horizon than in any other place of the heavens, although it is well known that these bodies are more remote from us than when we see them in the zenith?

Fanny.—As objects are usually presented to

our eyes with so much the more brightness as they are nearer to us, the habit of thus seeing them inclines us to think that these same objects are very far distant when they are more dusky. Thus, as the light of these bodies is then much enfeebled, we fancy that it proceeds from their being at a greater distance; and we judge in the same manner that they have approached us, when in rising more above the horizon they become more splendid. Now, though the visual angle be always the same, the object which it embraces should appear larger if we think it more distant. We therefore suppose the diameters of these bodies greater when they are in the horizon than when they are more elevated, because in this last case we think them nearer to us.

Lady Caroline.—Why, Mary, have the heavens the figure of an arched vault?

Mary.—Because they are much more enlightened toward the zenith, than toward the horizon; and thence it must happen that the hemispherical curve is changed into another apparent curve, which is extremely arched.

Lady Caroline.—An object does not appear double, although each of the eyes receives an image of the same object. Give a reason for this, Edward.

Edward.—If the mind refer the two images of the same object to the same place, the ob-

ject cannot appear double. The mind cannot see an object precisely double at the same point and at the same place. Now, it refers the two images to the same point, for it refers them to the extremities of the two optic axes; and these two extremeties terminate in the same point. Press the angle of one eye, so that the optic axes may not terminate at the same point as the other, the object appears double.

Lady Caroline.—How is it, Sophia, that an object which is differently coloured, for instance, one half red and the other blue, does not appear of a mixed colour?

Sophia.—It is that the prunella is not the last boundary of the rays which assemble there: this part of the eye is merely a simple opening. We should therefore conceive, that all these pyramids of light which terminate in the eye, pass without confusion through the prunella, and increase in it; after which they continue their road to the bottom of the eye, where each of them makes its impression separately from the other. Now all these impressions collectively form the image of the object.

Lady Caroline.—Why, Mary, cannot we move one of our eyes without moving the other?

Mary.—The immediate cause of muscular motion is such, that the spirits cannot penetrate into the one without flowing in the same manner and at the same instant into the other.

Lady Caroline.—Why, George, do objects, when the eye looks too near them, appear confused?

George.—The angles made by the rays being too great, and those which shoot from every point of the object too much asunder, are not re-united enough upon the same part of the retina?

Lady Caroline.—What is the reason, Kitty, that the stars are not visible in the day time?

Kitty.—The impression of the sun is a great deal too strong, and the vibrations of which it is the source in the organ of sight, repel that of the stars, and render them invisible.

From the bottom, however, of a deep tower, we see the stars in open day; because in the dark bottom the impression of the stars is stronger in its turn, since the rays of the stars fall therein perpendicularly upon the eyes, without having been weakened by any reflection; while the rays of the sun can only enter obliquely, and do not arrive at the eyes; or, if they do, it is not till they have been considerably weakened by a great number of reflections.

Lady Caroline.—Why, William, does a square tower, seen from a distance, appear round?

William.—As the angles of the tower do not make in the eye a sensible angle of vision, on account of its great distance, we cannot dis-

cern them; and as soon as we fail to distinguish the angles of the tower, it must of course appear round.

Lady Caroline.—What is the reason, Elizabeth, that on coming out of a very light place, and entering one that is rather dark, for some seconds after our entrance we cannot see any thing?

Elizabeth.—The prunella, which is contracted when in a bright place, that it may not admit the rays that might wound the organ of sight, remains thus for some moments after we have entered the darkened place, and admits not of the weaker rays of light sufficiently to perceive the objects.

When, on the contrary, we pass from a dark room into one that is very light, the impression of the latter is at first painful, because the prunella, which has been dilated in obscurity, in order to receive a greater quantity of the feeble rays, remains some time dilated in full light, and receives too many vivid rays; which excess wounds the organ of sight.

Lady Caroline.—What is the cause of the twinkling of the stars, Henry?

Henry.—We may attribute it to the motion of the media through which the images of these stars pass to come to us. These media, which are the air, &c. have a motion that is commu-

nicated to the rays of light, which enable us to see the stars; and hence they appear to twinkle.

Lady Caroline.—Why, Fanny, do certain portraits seem to look at us, let them be viewed whichever way they may?

Fanny.—Such portraits have the nose a little turned on one side, and the eyes toward the other. According as you are placed, they sometimes appear to look on one side, because the eyes are turned to that side; at others, we should think they looked on the other, because the point of the nose is turned thither; and the picture being flat, we do not perceive that the eyes are turned towards the opposite side.

Sir Thomas.—Every necessary principle having been previously laid down to you, we shall now proceed to that part of the present subject, which relates to

Reflected Light.

Lady Caroline.—Water alters the whiteness of paper, by making it appear more brown. How happens this, Mary?

Mary.—From the light which falls upon it, finding the pores filled with a transparent matter, absorbing itself in its thickness, passing beyond it, and returning with much less reflection. Now, we know that a body appears more obscure, when it reflects less rays.

Lady Caroline.—Why, Edward, can we not

make use of a simple plane mirror, however large it be, to collect the solar rays, and to increase the degree of heat that they produce?

Edward.—Because such a reflection does not change their natural parallelism; and we cannot expect an effect to happen that is produced only by their convergency: the direct light of the sun would be more efficacious, the mirror never being sufficiently perfect to reflect regularly all the rays that fall upon it.

Lady Caroline.—The light of wax candles has commonly an increased effect in places where there are cut-glass lustres and chandeliers. What is the reason of this, Sophia?

Sophia.—Independently of those small flames, of which the images are multiplied, more light returns from the polished glass than from any other reflecting body that may ornament them.

Lady Caroline.—Why, Frederic, have burning glasses such extraordinary power?

Frederic.—They re-unite the rays of the sun in a focus, which only contains a very small space. The rays of the sun being in a particular manner deemed parallel, those which are dispersed on the surface of the mirror are re-united in one point; and as this re-union much increases their strength, it is not surprising, that, separately having much heat, they burn and

melt whatever is exposed to the point of their re-union.

Lady Caroline.—The rays of the sun which fall upon mirrors have more strength to burn than those of a lighted fire. How happens this, George?

George.—The rays of the sun which fall on mirrors, being nearly parallel, the reflection or refraction re-unites them in a greater number upon the combustible body; and this superabundance of rays re-united is an excess of strength. The rays which proceed from the fire are less parallel, perhaps on account of the nearness of the fire, or because they are impelled with less force; they are therefore re-united in a smaller number upon combustible bodies, and the result of this defect of the re-united rays is a want of force.

Lady Caroline.—Why, Kitty, does a large mirror produce more effect than a small one?

Kitty.—It receives more rays, and reflects more of them to its focus.

An eminent philosopher (M. Buffon) by the means of a mirror of six square feet, was able to melt tin at 150 feet distance, lead at 140, silver at 50 feet, and to set fire to a block of wood at the distance of 200 feet.

Lady Caroline.—Why, Henry, do we in vain make use of convex mirrors to increase the heat that flows from the solar rays?

Henry.—The light of the sun being naturally almost parallel to itself, far from converging as it should do to acquire more strength, can only diverge and be rarefied when it is reflected by such surfaces.

Lady Caroline.—Why, Fanny, is the light which comes from the planets to us so very much weakened?

Fanny.—It not only makes a longer passage by flowing from its source to other celestial bodies, and from these to our globe, but, besides, there is only a small part of it reflected towards us, and the portion of light which is given to us, is very rarefied by the divergency it receives from the spherical nature of the reflecting surfaces.

Lady Caroline.—The heat of the sun is less powerful upon the summits of high mountains, than in valleys. Explain this, Mary.

Mary.—Among the causes which contribute to this effect, we may reckon the divergency of the rays of light, considerably increased by the round figure of the mountains; for the heat experienced on the surface of the earth darts not only from direct rays of the sun, but also from those that are reflected; these being rarefied or dispersed by the manner in which they reflect, the total effect must consequently be less.

Lady Caroline.—By fixing the sight upon a

gold or silver button, a watch-case, &c. well burnished, we may see our faces as in miniature paintings; they are seen also in their natural situations, and very near behind the reflecting surface, but we seldom see them correctly designed; and the motions of such representations do not correspond to those who consult them. What is the reason of this, Edward?

Edward.—It is probably occasioned by the irregularities of those little mirrors, which are adapted to shine, rather than to represent objects; but even if they were fitted for this last effect, they would always in common circumstances have the imperfections I before mentioned.

Lady Caroline.—Why, Sophia, does a concave mirror which has a very small curvature represent pretty accurately the figure of a small object; and the contrary, if it be more hollow in regard to its diameter, and the object be larger?

Sophia.—The dimensions of a large object not being parallel to the reflecting surface, and the visible points being represented at distances proportionate to the degree of the distance which they have before the mirror, it is natural that the images which result from all these particular representations should make us see in curve lines that which is represented in the

mirror in straight lines; or, which is the same thing, the apparent figure is not conformable to the real figure of the object.

Lady Caroline.—Why, Frederic, do plane mirrors represent objects just as they are, without changing either the colour, the arrangement, or the size of them?

Frederic.—Being hard, uniform, and polished, they send back to us the rays as they received them, in the same order, and with the same modification; the angle of reflection being equal to that of incidence.

Lady Caroline.—The object appears beyond plane mirrors at the same distance as it is, or appears to be, on this side of the mirror. In proportion as I approach the glass, or remove from it, my image, which is seen beyond it, seems to approach or remove as I do. What is the cause of this, George?

George.—The rays, before they represent the object, go from the same object to the glass, and come back from beyond the glass even to the eyes. They have, therefore, when they enter into the eyes, not only the same disposition and inclination, but likewise the same force and direction, which they would have, if they had actually come from the point, and the distance where the object appears beyond the mirror. Of course, they ought to represent it there as they really do, so much the more as

the mind naturally refers objects to the extremity of the right rays, which approach to strike the organ, or which face you.

Lady Caroline.—Sometimes the light of a single wax-candle, falling upon a pane of glass with an obliquity of forty-five degrees, appears double beyond it. Why so, Kitty?

Kitty.—It is, because there is a stronger light and one more weak; the stronger one is reflected by the foremost surface of the plane of the glass, and the weaker one is sent back, at least in part, by the air expanded upon the hindermost surface. If we moisten with water, clear oil, or transparent and liquid honey, that surface, a great part of the rays will no more return, because these fluids will not allow them to pass. The rays return, however, when the air alone immediately covers the surface.

Lady Caroline.—Why do convex mirrors represent objects smaller than they really are; and concave mirrors, on the contrary, larger? Can you tell me, William?

William.—The convexity of the first is the cause that the most powerful rays are reflected to the eye only by a very small surface. They strike the eye under very small angles. Thence the angle of vision is extremely minute, and the image of the object corresponds to this angle.

The concavity of the latter is, that the rays reflected by the concave surface make a much greater angle; and if we look within it, the object of a point where the eye may be more remote than the focus of the rays, or than the point of their re-union, the object appears inverted; because the rays must cross each other in their focus, and then separate in such a manner, that those which come from the superior part of the object are downwards, before they enter into the eye; and those which come from the inferior part are upwards.

Sir Thomas.—The part of this subject with which we are now about to close, is called

Refracted Light.

Lady Caroline.—We should infallibly miss a fish in the water if we shot at the place where we see it. How does this happen, Elizabeth?

Elizabeth.—For two reasons; the first is, because the fish is always lower than the spot in which it appears to be. In the second place, the ball undergoing a refraction in a contrary direction to that of the light, necessarily rises above the direction which we intend to give it.

Lady Caroline.—How is it, Henry, that we sometimes see the moon on her rising, totally eclipsed, while the sun is still wholly seen in the opposite part of the horizon?

Henry.—It is not the moon that is shewn

upon the horizon, but only its representation raised by the effect of refraction.

Lady Caroline.—Plane glasses, as those which are put in windows, or made into mirrors, cannot be used to condense the solar light which runs through them. Give me the reason of this, Fanny.

Fanny.—These rays, being parallel to each other, can never be more inclined than the other to any single plane: thus, refractive surfaces that are even, do not change any thing in their respective position.

Lady Caroline.—How is it that we see, Mary, through the glasses of carriages, almost, if not quite, as well as if we looked simply through an homogeneous medium?

Mary.—When media more dense than the air have even surfaces, and those very fine, their interposition does not cause any sensible change in images, because the light is but little refracted.

Lady Caroline.—Dense media, very thick, although with plane surfaces, make us see objects much larger than they are; fish, for instance, appear larger in water than when they are taken out; gravel, stones, and plants, in like manner, deceive us when we see them at the bottom of basons, fountains, rivers, &c. The spaces also appear more extended, and the li-

mits which surround them seem to leave betwixt each other a greater distance. What reason, Edward, can be given for this?

Edward.—It may be accounted for by the rays, which become more and more converging when they dart from the water to enter into the air.

Lady Caroline.—Having the eye placed directly above a vessel full of water, if we look at a piece of money at the bottom of the vessel, it appears larger than in the air; but it does not seem to be out of its place, like another substance of which we shall hereafter speak. What is the cause of this, Sophia?

Sophia.—In this case, Madam, the eye perceives a part of the piece; its centre, for instance, through a cluster of rays, of which the axis suffers no refraction, perpendicularly passing from the water into the air: this part of the piece is therefore seen in its true place, and in its natural direction; the others are seen by oblique rays, of course reflected, which apparently disperse them from the first, as if it were immoveable; hence the object appears magnified, but not displaced as to its direction: the figure itself is not sensibly altered, if we direct our look in such a manner that the direct ray may come from the middle of the object

which we propose to see, at least if it be not too large.

Lady Caroline.—Solid bodies put in glass vessels full of water, or any other transparent fluid, appear under deformed shapes when we look at them through the sides of these vessels, which are often curved in one sense and straight in another. What is the cause of this, George?

George.—There are certain dimensions, as in these instances, which admit more than others of the effects of refraction.

Lady Caroline.—If you put a crown piece or any other piece of money into an empty bason, and withdraw till you just lose sight of it; and another person come and put a certain quantity of water gently into it, so as not to move the piece, it will, nevertheless, suddenly appear to you again. Can you explain the cause of this, Kitty?

Kitty.—The opposite sides of the bason hinder the rays which shoot from the surface of the piece of money from coming in a direct line to our eyes. If we fill the bason with water, we may see the money at the same distance in the opposite points of the curve of the bason, beyond and above the spot where it really lies.

Lady Caroline.—Certain artists in fine works, as engravers, &c. for the purpose of procuring

light for their evening labour, have lamps, of which they make the light pass through a glass bottle, thin, round, and clear, which is called the jug, and which is filled with clean spring water. For what purpose have they recourse to this expedient, William?

William.—The flame of a candle or of a lamp being placed near this bottle, throws upon a great part of its spherical surface diverging rays, which become by degrees a great deal less; and this light afterwards loses the rest of its divergency, by passing through the water into the air, because on each part it is refracted; the rays of course are contracted into a smaller space, and become parallel or converging.

Lady Caroline.—Why, Elizabeth, does a straight stick put obliquely into water, appear broken?

Elizabeth.—The rays which shoot from the end of the stick, are refracted in their entrance from the water into the air, and the eye receiving them as if they were shot from a point where the end of the stick is not, the mind is referred thither, and thinks it broken asunder.

Lady Caroline.—Why, Henry, do round magnifying glasses, or lenses, enable us to see more clearly?

Henry.—As they are convex on both sides, they force rays to enter into the eye, which

would not have entered had we looked at the object without them; it is a natural consequence that they will render the light less diverging, for the refracted rays being more contracted between themselves, the prunella must seize those which might have escaped.

Sir Thomas.—We are now, my dear children, arrived at the end of our labour. My design is completed. I am convinced that you perfectly understand all the questions and principles which have been proposed and expounded by your good mother Lady Caroline, and myself.

You will now be able with confidence to account for every phenomenon that can occur in common life. Many things of which great numbers of people, who are considered as having been well educated, are completely ignorant, you will be enabled to explain to their great astonishment and admiration.

We shall now leave you to cultivate and improve whatever new ideas may arise upon the subjects of which we have been treating; and I trust that your own ingenuity will prompt new and useful experiments, which your industry will bring to perfection.

A

VOCABULARY

OF THE

SCIENTIFIC OR TECHNICAL

TERMS,

OCCURRING IN THIS VOLUME.

A

ABSOLUTE—complete, unlimited.

Absorbent—the property of sucking up or drying away moisture.

Accelerated—one increase of swiftness continually added to a former increase.

Accord—when two or more sonorous bodies form sounds, the union of their impression is called an *accord*.

Acids—liquors and substances which being composed of pointed particles affect the taste in a sharp and piercing manner, as vinegar, lemon-juice, &c.

Action—the power of one body exerted on another.

Active—a body that can exert its power on another.

Acute—sharp; ending in a point; the highest sound of an instrument.

Adherence—the union of two bodies simply touching each other.

Adipous—fat, greasy.

Adulterated—the mixture of some base matter, which renders a substance corrupt, unwholesome, or nauseous.

Agate—a hard, parti-coloured, and smooth stone.

Air-pump—a machine by which the air contained in all bodies may be exhausted.

Alkali—any substance which when mingled with acids produces fermentation and effervescence.

Alternatives—the various successions or situations of one thing to another; the choice given of two things, so that if one be rejected, the other must be taken.

Aluminous—belonging to, or containing alum.

Amphibious—having power to live either on land or in the water indifferently.

Analogous—bearing some resemblance or proportion.

Angle—the ends of two lines inclining to, and meeting each other, form an opening or corner called an *angle*. An angle is called *acute* when the two lines that form it contain between their open ends a less portion than one-fourth of a circle's circumference. It is called *obtuse*, when its lines contain more than one fourth of a circle's circumference. It is a *right angle*, when they contain exactly one-fourth of a circle's circumference.

Angle of Incidence. See the definition of *Light*, p. 338.

Angle, optic. See the definition of *Light*, p. 338.

Animalcule—the smallest of all possible insects, which, without the help of glasses, escape the most piercing eye.

Antipathy—a natural contrariety to any thing so as to shun it involuntarily; aversion, dislike; the contrary to *sympathy*.

Apex—top, point, or summit.

Apices—plural of *apex*.

Apparatus—things to be provided for the purpose of experiments.

Application—the fitting of one thing to another, and the agreement of both.

Aqua-Fortis—a powerful liquid, composed of salt-petre and vitriol.

Aquatic—residing in water.

Aqueous—watery.

Aqueducts—conveyances for water.

Arcana—secrets; alluding to the secret stores of truth found by philosophy in the womb of nature.

Asperities—roughnesses on the surface of any natural body.

Atmosphere—the air that surrounds the globe of the earth; the odorous particles which surround a flower; the effluvia of a heated body.

Atoms—the most minute and invisible parts which constitute bodies; any thing extremely small.

Auditive Nerves—the seventh pair of nerves, and which convey sounds to the ear.

Axis—a direct line passing through the centre of any body on which it may turn.

Axes—plural of *axis*.

B

Bamboo—a reed found in the East Indies.

Basis—the foundation or ground-work of all bodies.

Bas Relief—a projected ornament, which does not stand out from its ground in full proportion.

Biped—any two-footed animal.

Bodies—all those things which can be called substances, have a shape or form, and may be felt or known by the senses.

Boerhaave—a celebrated Dutch natural philosopher, born 1668, died 1738.

Bomb—a shell or hollow ball of cast-iron, charged with powder, nails, &c. formidable in war.

Breadth—the measure of a body from side to side.

C

Calcination—reducing of bodies to powder by fire.

Calculate—to compute, to number, to reckon.

Capacity—the quantity of room that a body has to receive other bodies within it.

Capillary tubes—small tubes or conveyances in different bodies, resembling hairs in their capacities.

Caput mortuum—passive or inactive dry earth.

Cardinal point—one of the four principal points in the compass.

Catoptrics—that part of optics which treats of vision by reflection.

Cause—that which produces an effect.

Centre of gravity—a point through which any body may be divided into two equal parts, that is, one as heavy as the other; the very centre point, of the weight of all bodies.

Chrysalis—any insect in its *coque* or egg-shell.

Cinnabar——vermilion, a heavy red mineral, consisting of united particles of mercury and sulphur.

Circle—a circle contains 360 degrees, 21,600 minutes of degrees, and 1,296,000 seconds of degrees.

Coagulate--to congeal, thicken, or curdle together.

Cochineal--an insect, which, when properly dried, is used in the dyeing-trade.

Cohesion—the union of two bodies in such a manner as to require force to disjoin them.

Column——a round pillar; any body of certain dimensions pressing vertically upon its base.

Combination——the different ways that quantities or substances may be varied in order to produce a new form.

Compass—an instrument dividing the horizon into 32 equal parts; by this instrument mariners steer their course.

Composition—a mixture of different ingredients to constitute one whole.

Compound——a substance made up of many ingredients.

Compression——a thickening or squeezing together, so that, though the bulk lessens, the contained matter is still the same.

Concave—a cavity or regular curved hollow.

Concussion—a sudden shock, or loud and tremendous clashing.

Condensation--the same with *compression*; the opposite to *rarefaction*.

Conformation—the way in which the elementary parts of a body are disposed and arranged.

Congenial—similar disposition and temperature.

Conglomerated--gathered together, as in a swarm or a ball, or any round mass.

Consecutively—following in train, successive, uninterrupted.

Constituent——those parts which placed together form a whole.

Consumption--the expending of strength.

Contiguity—the nearness of

two bodies so as to touch each other.

Continued body—a substance so conceived that its parts are not separated from each other.

Contraction—that kind of motion which makes a body collect its parts into each other, gather up, as it were, and shorten itself.

Converging rays--rays which incline towards each other till they meet in a point.

Convex—a form round like the top of a watch-glass, as a concave is hollow like the inside of a watch-glass.

Cornea--the second or horny coat of the eye, containing the watery humour.

Corpuscula—the smallest of all bodies.

Cubic inch--is an inch square made into a solid body like a die, whose length, breadth, and depth are equal.

Curving---crooked, bent, arched.

Cylinder--a body having two flat surfaces and one circular; a tube or pipe completely round and uniform from one end to the other.

D

Day—contains 24 hours, or 1440 minutes.

Degree—contains 60 minutes, or 3600 seconds. Equal to $69\frac{1}{2}$ English miles.

Density—thickness; or that property by which bodies contain such a quantity of matter under such a bulk; so that more matter under the same bulk is greater density.

Depth—the measure of a body in the direction of from head to foot.

Descartes—a celebrated French philosopher, born 1596, died 1650.

Deterioration—the contrary of improvement, the act or state of becoming worse.

Determined—fixed to one direction, ordered, necessitated, limited.

Diagonal--a line drawn from angle to angle, and dividing a square into equal parts.

Diameter—a straight line passing through the centre of a round table (for instance) and ending in two opposite points of the rim.

Diaphanous—transparent, allowing the light to pass through, as glass, air, water, &c.

Diffusion of odours—the dispersion and spreading round of fine vapours.

Digestion—the action by which the grosser parts of food are separated by the heat of the stomach, and certain internal juices from those which are more fine and subtile.

Dilatation—the act of becoming thin and wide, so as to preserve the same quantity of matter, but acquire a larger volume; contrary to *contraction*.

Dilute—to melt down; the word is generally used to imply several substances washed into each other by long mingling and beating together.

Dimension—the measure of a body, either as it is long, broad, or deep.

Dioptrics—that part of optics which treats of the different refractions of light passing through different me-

diums, as air, water, glass, &c.

Direction—a straight or crooked line from the place of setting-off to the place of arrival.

Disk--the body or face of the sun or moon being round and appearing to our sight as flat.

Disseminated ——— spread throughout, like seed in a field.

Dissolution—a loosening asunder, so as to divide the particles of solid bodies from each other.

Divergent rays—rays which going from the point of any visible object, depart from each other.

Divisibility—the quality of admitting division or separation of parts.

Ductility of metals—the quality that metals have of becoming flexible, pliable, and extendible.

E

Ebullition—-boiling or bubbling upwards through great motion.

Effervescence--a boiling over.

Effluvia—the small and insensible particles that fly off from bodies.

Elasticity—the power to return to a first situation, as a cane that is forcibly bent flies back again.

Electrical—-bodies which have the power of attracting light substances to them without magnetism; amber, sealing wax, &c. when heated by friction, are of this description.

Elements—the original, unmixed, simple parts of any created substance.

Emanation of Light—flowing round in all directions from a source or centre, as the rays of light from a taper or from the sun.

Enveloped—inwrapped, covered, surrounded, inclosed.

Eolipile—a hollow ball of metal with a long pipe; which ball filled with water, and exposed to the fire, sends out as the water heats, at intervals, blasts of cold wind through the pipe.

Equilibrium—equipoise, equality of weight at each end.

Essence—the very *being* of a thing.

Evacuation—-the act of emptying.

Evaporate—sending out vapours from the substance of the body itself.

Exhale—throwing forth vapours from the surface only.

Expansion—the swelling or increase of bulk of fluids when stirred up by heat.

Experiment—a trial made on natural bodies for the purpose of discovering their qualities or their properties, and ascertaining their causes and effects.

Expirate—vapours thrown forth from a hollow substance.

External—-from without; that is, a cause not within the body itself, but proceeding from some other body.

Exudation—a forcing out of the juices.

F

Faces—small surfaces; a superficies cut into several angles.

Fermentation—an internal motion of the imperceptible parts of a body, accompanied with great expansion occasioned by the *acids* making their way into the *alkali*.

Fibres—fine ligaments or strings, tough and long, the middle part of which is very fleshy.

Filaments—thin, slender threads; also small fibres which make up the texture of the muscles.

Fluids—liquids, any thing not solid; those bodies which are made up of particles so very small and round, that they are easily put in motion by touching each other only in one point, like so many small globes.

Finite—that which has an end; it also means determinate.

Focus—the point wherein the rays are collected after they have undergone refraction or reflection.

Foci—plural of *focus*.

Force—power, impulse.

Form—the external appearance or shape of any thing.

Frangible—easily broken.

Friction—the rubbing of two bodies against each other, so as to hinder or lessen motion.

Fulcrum—a prop.

Function—the office allotted to any active power.

Fusion—the act of melting, the state of being melted.

G

Globules—small round bodies.

Gold putty—a cement or paste made of gold in the way of common putty.

Graduation—by degrees, step by step, regularly slow.

Grain—the weights here following are generally used in the experiments of natural philosophy:

One pound contains 12 ounces, or 240 pennyweights, or 5,760 grains.

One ounce contains 20 pennyweights or 480 grains.

One pennyweight contains 24 grains.

Gravity—weight, heaviness, tendency to the centre.

H

Hartsoeker—an eminent Dutch philosopher and mathematician, born 1596, died 1650.

Hemisphere—the half of a globe or sphere when divided in two by a plane passing through its centre.

Heterogeneous—consisting of parts unlike each other.

Horizon—the line that terminates our view of the sky.

Horizontal—level with the horizon.

Hour—contains 60 minutes, or 3,600 seconds.

Humidity—moisture, wetness.

Hydrostatics—the science which treats of the nature, gravity, pressure, and motion of fluids, and of weighing solids in them.

Hypothesis—supposition; principle laid down, and to be taken for granted.

I

Igneous—the property of those bodies which communicate fire.

Impelled—pushed or driven onwards.

Impregnated—filled so as to admit no more.

Inch square—is a portion of any substance of four equal sides, every one of which is an inch in length. Natural philosophers use the following measures in their experiments on space:

12 inches make 1 foot.
3 feet —— 1 yard.
6 feet —— 1 fathom.
$5\frac{1}{2}$ yards —— 1 pole, perch, or rod.
40 poles, &c. —— 1 furlong.
8 furlongs 1 mile.
1 linear foot makes 12 linear inches.
1 linear inch makes 12 linear parts.
1 square foot —— 144 square inches.
1 square inch —— 144 square parts.
1 cubic foot —— 1728 cubic inches.
1 cubic inch —— 1728 cubic parts.

Inclined Plane—a surface that slopes or inclines to the level of the horizon.

Incorporated—two bodies so joined that a distinction of either becomes difficult.

Inertness—the state of being quite still.

Infinite—without end; indeterminate.

Inflexibility—incapable of being bent or wrought upon.

Influence—the power of one body flowing in upon another, and giving or depriving it of exertion.

Infusion—the state of being steeped in moisture, or poured upon.

Integrant parts—are those which collectively make up a whole body.

Internal—inward, not external.

Interposition—a placing betwixt, or one body placed between two others.

Interstice—space between one thing and another.

Intimately—closely, with intermixture of parts.

Inverse ratio—inverted proportion; reciprocal; opposed to *direct*.

Julian month—contains 4 weeks, or 28 days, or 672 hours, or 40,320 minutes.

Julian year—contains 13 months, 1 day, and 6 hours; or 52 weeks, 1 day, 6 hours; or $365\frac{1}{4}$ days; or 8766 hours; or 525,960 minutes.

K

Kind—the word *kind* makes one's thought general, as *mankind* means all the human race together. See *Species*.

L

Layer—a thin covering of any one substance spread upon another, or a continued bed of any kind of substance, such as a bed of a peculiar sort of clay in the bowels of the earth.

Length—is the measure of a body from the face onwards; from end to end.

Lever—any contrivance to enable us to raise a body that is either too heavy or too inconveniently placed to be raised by the mere strength of the arm. See p. 97.

Line of direction—is that line which proceeds from the centre of gravity, and determines the motion of the body to such and such a direction.

Litharge—a coarse kind of reddish mineral; properly, lead vitrified, either alone, or with a mixture of copper.

Local—being in a particular place.

M

Machine—any complicated work in which one part contributes to the motion of another.

Magnetised—having the power of a magnet given to it.

Mairan—a French natural philosopher of the last century.

Mass—a body, a lump, a continuous quantity.

Matter—is every substance that may be felt, divided, put in motion, or stopped, and is extended in length, breadth, and depth.

Mechanical powers—See p. 94.

Medium—a peculiar constitution or frame of any space through which bodies move, as air, water, vapour, &c.

Media—plural of *medium*.

Membrane—this term is used to express a filmy web of fibres or small threads which envelope or cover the particular parts of an animated body.

Mercury or *Spirit*—is a white fluid mineral, the great principle of all metals, the first of fluid or flowing bodies, and only the second of heavy ones, as gold alone is heavier.

Microscope—an instrument by means of which the most minute objects are represented to the eye as of a prodigious size, and every part distinctly.

Miles reduced.—In this place it may not be amiss to remind the young reader of the following measures:

3 inches make a hand-breadth or a palm.
3 palms —— a span.
$1\frac{1}{3}$ span —— a foot.
$1\frac{1}{2}$ foot —— a cubit.
2 cubits —— a yard.
$1\frac{1}{4}$ yard —— an ell.
$1\frac{1}{3}$ ell —— a pace.
$1\frac{1}{5}$ pace —— a fathom.
$2\frac{3}{4}$ fathoms —— a perch.
4 perches —— a furlong
8 furlongs —— a mile.

Minute—contains 60 seconds.

Mixed bodies—implies whatever substance is made up of a mixture of the first principles or elements.

Modification—a qualifying or modifying; setting a measure or limit to any thing.

Muller—a stone held in the hand, with which any powder is ground upon a horizontal stone. It is often improperly called *mullet*.

Muschenbroek—a famous Dutch philosopher and mathematician, died 1761, aged 69.

Muscles—the principal organs or promoters of motion in all animated bodies.

Mutual—the quality of two bodies partaking of each other's powers.

N

Nature—a regular course of things; a disposition of bodies, a state, a system.

Nitre—a very sharp and corrosive body, drawn from salt-petre.

Nitreous—impregnated with nitre.

Non-elastic—bodies that do not restore themselves to their former figures after having been struck and bent by other bodies.

Nutrition—the act of nourishing.

O

Object—is the knowledge resulting from any particular study; as *subject* is the means of arriving at that knowledge.

Oblique—aslant, or forming an angle with the perpendicular line.

Obliquity—slantness.

Obtuse—blunt, the contrary to *acute*.

Oleaginous—partaking of the nature of oil; oily.

Opacity—cloudiness; want of transparency.

Opaque—dark, obscure, cloudy, the contrary to *transparent*.

Organ—the instrument of some faculty; thus, the *eye* is the *organ of sight*.

Orifice—hole, opening.

Orpiment, *yellow*—a species of arsenic.

P

Parallel—equally or every where alike distant.

Particles—the very smallest points or atoms that can be conceived to enter into the composition of bodies.

Passive—a body which must receive action from another, being incapable of action in itself.

Percussion, *direct*—a striking in a straight line.

Perpendicular—in the direction of a straight line up and down.

Perrault—a French natural philosopher, which profession he quitted for that of an architect. Died 1688.

Phenomenon—an uncommon appearance, difficult to be accounted for.

Philosopher—a man deep in knowledge, either moral or natural; literally, a lover of wisdom.

Phlegm—(pronounced *fleme*) a watery humour of the body so called; water, one of the five chemical principles.

Phosphorus—a chemical preparation which shines only in the dark, and being exposed to the air, takes fire.

Physics—natural philosophy, or that science which treats of the powers and properties of bodies in their *natural* state.

Plane—a flat surface level with the horizon.

Platen—a plate upon which objects are placed in the air-pump.

Pneumatics—the doctrine of the air, and of the effects dependent on its properties.

Pores—small openings found between the particles of all bodies.

Porphyry—a fine species of hard and reddish marble.

Precipitated—expresses the idea of suddenly sinking.

Precipitation—the sinking down of the particles of any mixed body that were kept propped up in a dissolving liquid.

Preliminary—going before; principles laid down previous to entering on the main subject.

Pressure—one body lying upon another, and forcing it to remain motionless by its weight upon it.

Plane, inclined—one of the mechanical powers. See p. 110.

Principles—the first particles that the mind can conceive in the constitution of any being.

Prism—a prism of glass is a glass bounded with two equal and parallel triangular ends, and three plain and well-polished sides which meet in three parallel lines, running from the three angles of one end, to the three angles of the other end.

Process—the way of proceeding in and conducting any experiment.

Prominences—little heights on the apparently smooth surfaces of bodies.

Proportion—comparative relation of one thing to another; ratio.

Prunella,—a small aperture in the middle of the eye; the pupil.

Pulley—one of the mechanical powers. See p. 104.

Q

Quality—the property by which one thing is distinguished from another.

Quantity—that property of any thing which may be increased or diminished.

Quicklime—lime unslacked with water.

Quotient—in arithmetic, the number produced by the division of two given numbers one by the other.

R

Radiant point—See the definition on *Light*, p. 340.

Rarefaction—the same with *dilatation*; which see.

Ray or *Radius*—that line which proceeds from the centre of a circle, and ends in some points of its circumference; a beam of light. *Solar Ray*, ray of the sun.

Reaction—resistance.

Recipient—that part of the air-pump which encloses the bodies that are put therein.

Reciprocally—returning equally on both sides; affecting both parties alike.

Reflection—means a *return back*, or the regressive motion of a body flying back from an obstacle.

Reflective—capable of reflection; that which reflects or returns back.

Refraction—means *breaking against*, or a bending or sliding of a body from its direct course.

Relation—the connection that two quantities have to each other with regard to their size or magnitude.

Reparation—the regaining of strength consumed.

Repulsion—a beating or driving back.

Respective—relative to any other body; the respective or different properties of each body.

Retarded—velocity or swiftness continually diminished; the contrary to *accelerated*.

Retina—the expansion of the optic nerve on the inner surface of the eye, is so called from its resemblance to a net.

Reverberation—causing the light of a body to strike and beat back again; beating or driving back.

Rotation—a wheeling round itself.

S

Saline—partaking of the nature of salt, one of the five chemical principles.

Salt—a mixed body, of which earth is the predominant or first principle, water the second, and fire the third.

Science—a clear, obvious, and certain knowledge of things founded on truth.

Scintillation—sparkling; the trembling and twinkling motion of the stars.

Screw—one of the mechanical powers. See p. 108.

Second—the 60th part of a minute.

Serosity—waterishness; the thin or watery part of the blood.

Sine—a right line drawn from one end of an arch per-

pendicularly upon the diameter drawn from the other end of that arch.

Siphon—an incurvated chemical tube or pipe.

Solar—belonging to or proceeding from the sun.

Solids—the parts containing the fluids; hard bodies, having length, breadth, and thickness.

Space—room, local extension, any quantity of place, or of time.

Species—this word makes our thought particular; as the Moors are a part of mankind. It is a subdivision of *kind*, as the peacock is a *species* of the feathered *kind*.

Specifically—peculiar to, and distinguished from others; the relation of different bodies to each other.

Sphere—a globe, an orb, a body of which the centre is at the same distance from every point of the circumference.

Stalactites—petrified drops of water, hanging like icicles from the tops of caves, &c.

Sublunary—any thing considered as being under the moon, or within her orbit.

Substance—being; something existing; solid, not empty; that which makes a being perceivable by the senses.

Subtile—thin, not dense nor gross; any invisibly fine matter, as the particles of fire, spirits, &c.

Succedaneum—one substance or body substituted in place of another.

Sucker—that part of the air-pump which draws up and exhausts the air.

Sulphur, or *Oil*—is a mixed, inflammable body, made up of fire, oil, water, and earth. In this mixture fire occupies the first place, oil the second, water the third, and earth the last.

Superficies—the whole of the outward parts of bodies; surfaces.

Surface—superficies, outside; that of which we only consider the length and breadth; thus an acre of ground is looked upon as a surface, because, when it is measured, its breadth is never taken into consideration.

Susceptibility—a disposition of easily receiving impressions.

Sympathy—something felt by two beings in the same way; the contrary to *antipathy*.

Syringe—a pipe through which any liquor is squirted.

T

Tangent—a line that just grazes the surface of a circle, or touches it in only one point.

Tension—a bending or stretching out by the force of another body; the state of being stretched.

Tenuity—thinness; smallness, minuteness.

Terebinth—a clear gum or resin issuing from several sorts of trees; turpentine; oil.

Texture—the manner in which the elements of any

particular body are interwoven with each other.

Transpiration—emission in vapour; a suffering of the juices to evaporate.

Treble--the most acute string of any instrument of music.

Trepidation—trembling; a gentle agitation; a kind of soft trilling motion.

Trigged—the use of an iron cramp or hook, that being affixed to one of the wheels of a carriage when going down a hill, prevents its turning round like the other wheels, and thereby hinders the too quick motion of the carriage down a declivity.

V

Vacuum--a very small space intervening between all globules.

Vapours—the minutest particles of any fluid raised into the air by means of the sun's heat, or by any other fire.

Velocity—-swiftness; the property of a moving body to run over such and such a quantity of space in such and such a portion of time.

Vertical—in a direction perpendicular to the horizon.

Vibration—the quivering of a musical string with quick or slow trepidation, producing sound. *Particular vibrations*, the imperceptible parts of a musical string; they vibrate like the *total vibrations*; they produce sound, and are of course their elements. *Total vibrations* are the trepidations of the whole sonorous body, which quivers only, but produces no sound.

Vitrify—to become glass, to be changed into glass.

Void—a vacuity or space wherein nothing is contained; a total emptiness and absence of every kind of matter.

Volatile—-bodies that are apt to evaporate or resolve themselves into air, are said to be *volatile.*

Volume—the quantity of room that any substance or body takes up in space.

Vortex—a fluid of any kind, in which the suction is circular.

U

Undulation—a motion like that of the waves, waving to and fro in the air, the motion of a worm on the ground.

Unison—one and the same sound; the agreement of two notes or strings of an instrument in one and the same tone.

W

Water—a transparent elementary liquid, tasteless, without colour or odour, penetrating the pores of most bodies, convertible into ice, and capable of extinguishing fire.

Wedge—a body with a sharp edge. See p. 107.

Week—contains 7 days, or 168 hours, or 10,080 minutes.

Wheel and *axis*—one of the mechanical powers. See p. 102.

Z

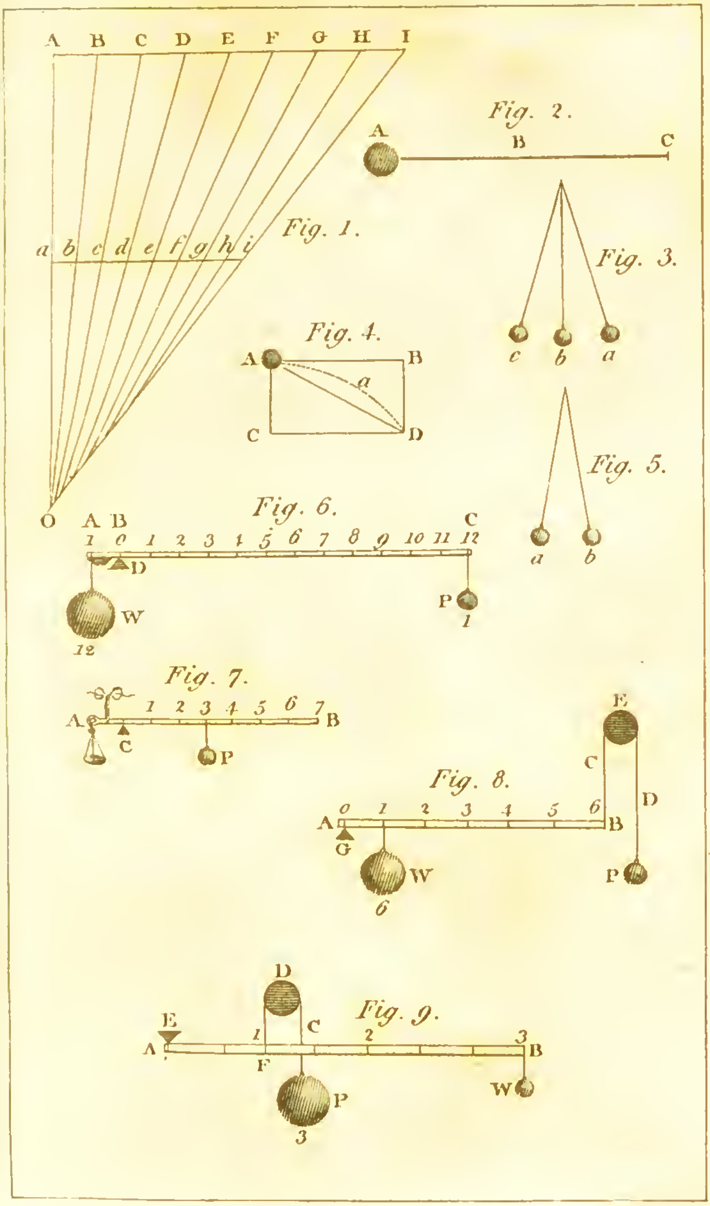
Zenith--the point over head, the vertical point.

Zone—a girdle, belt, spaces or boundaries circularly described on certain bodies; a division of the earth; circuit, circumference.

FINIS.

Brettell, Printer,
Marshall-street, Golden-square.

Plate I



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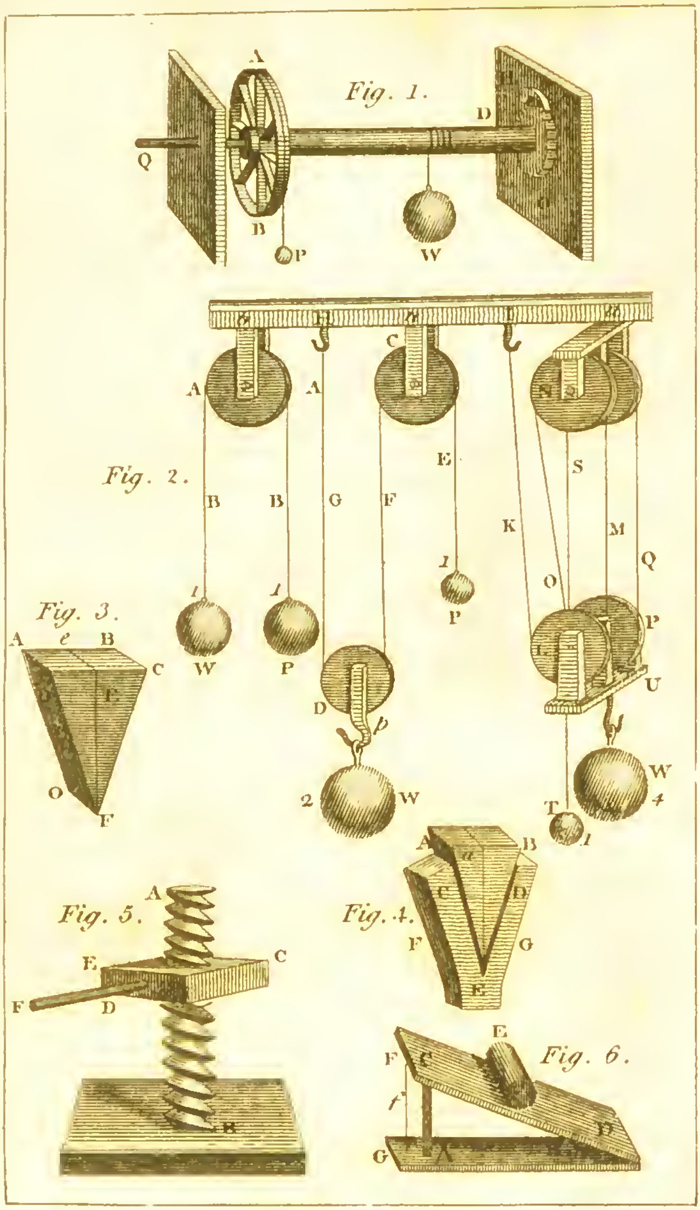

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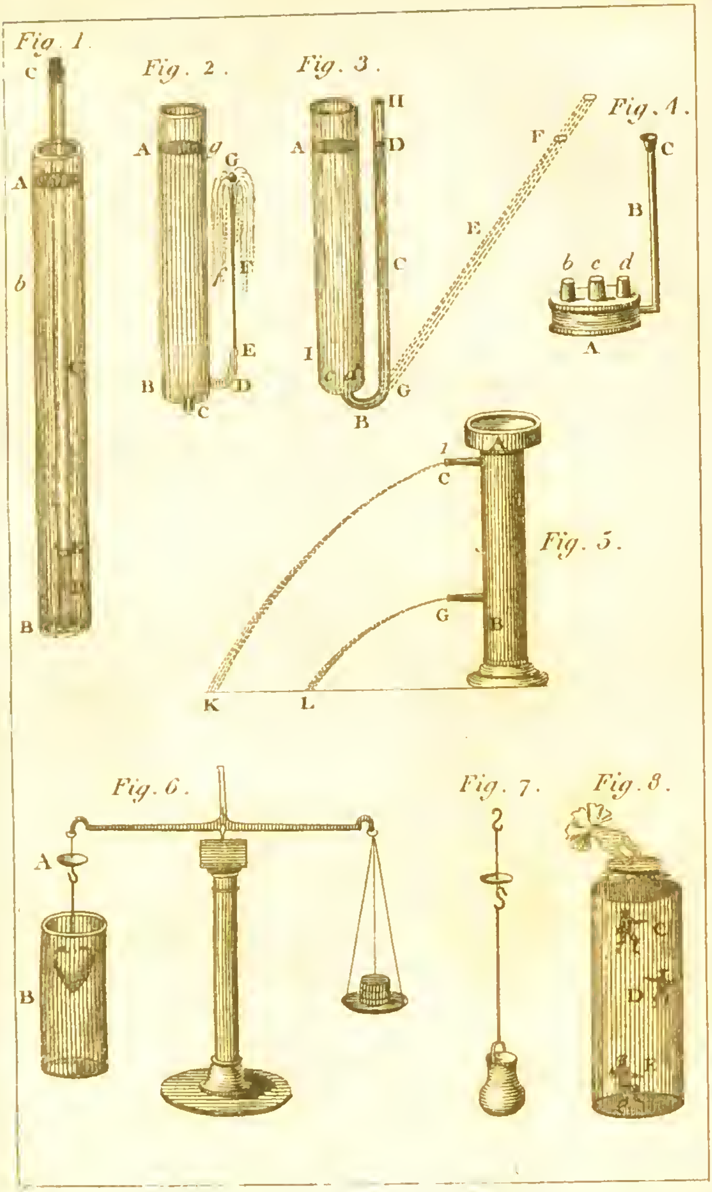

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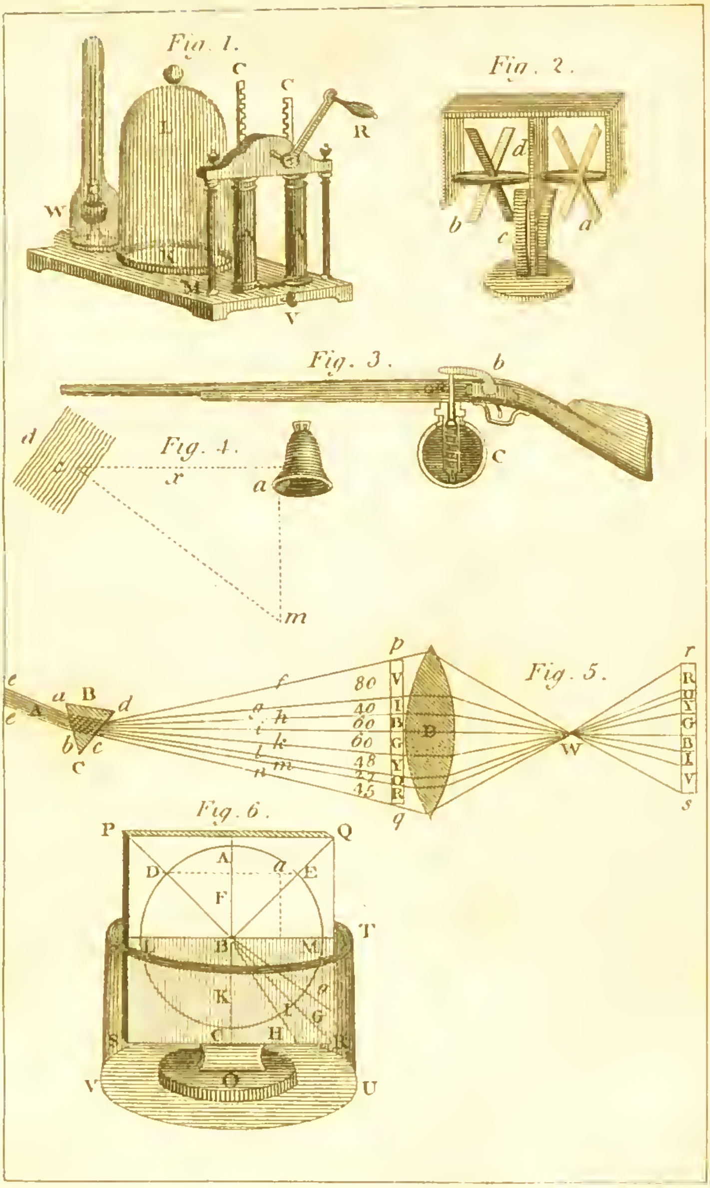
Plate IV.



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